ASTRONOMY

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Astronomy on La Palma

Total Eclipse in New Guinea

Cold Dark Matter and the Origin of Galaxies

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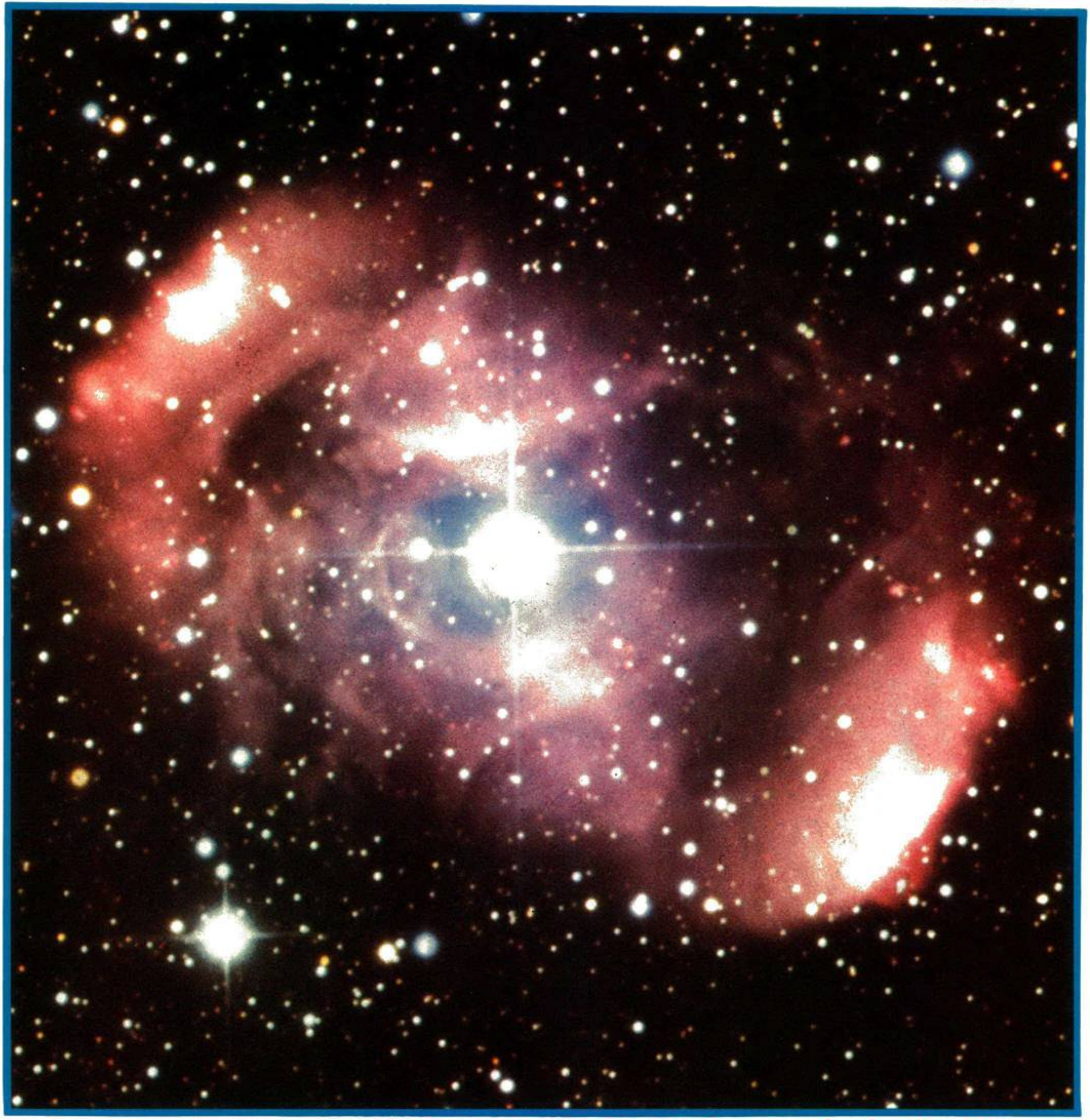

NGC-6164/5: Emission Nebula in Norma

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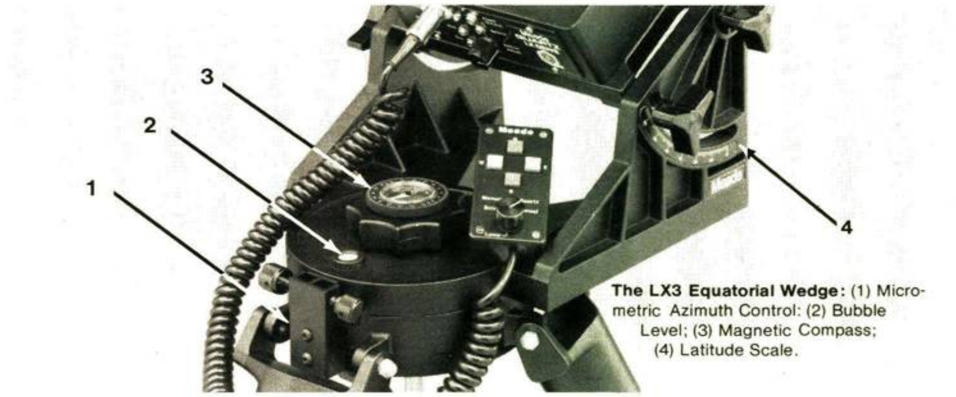

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Cover: British observational astronomy is on the rebound after years of neglect. New optical telescopes in Australia and the Canary Islands have once again placed the U.K. at the cutting edge of research. Our cover shows NGC 6164/5, a nebula in the southern constellaton Norma, photographed with the 3.9 meter Anglo-Australian Telescope. Copyright © 1981 by the AAT Board. These pages: The British pioneered radio astronomy, then lost the lead to workers in other countries. The venerable 250-foot radio telescope at Jodrell Bank, the world's largest when built in 1957, is now part of a network of powerful radio telescopes called Merlin. Photo courtesy of Nigel Henbest.

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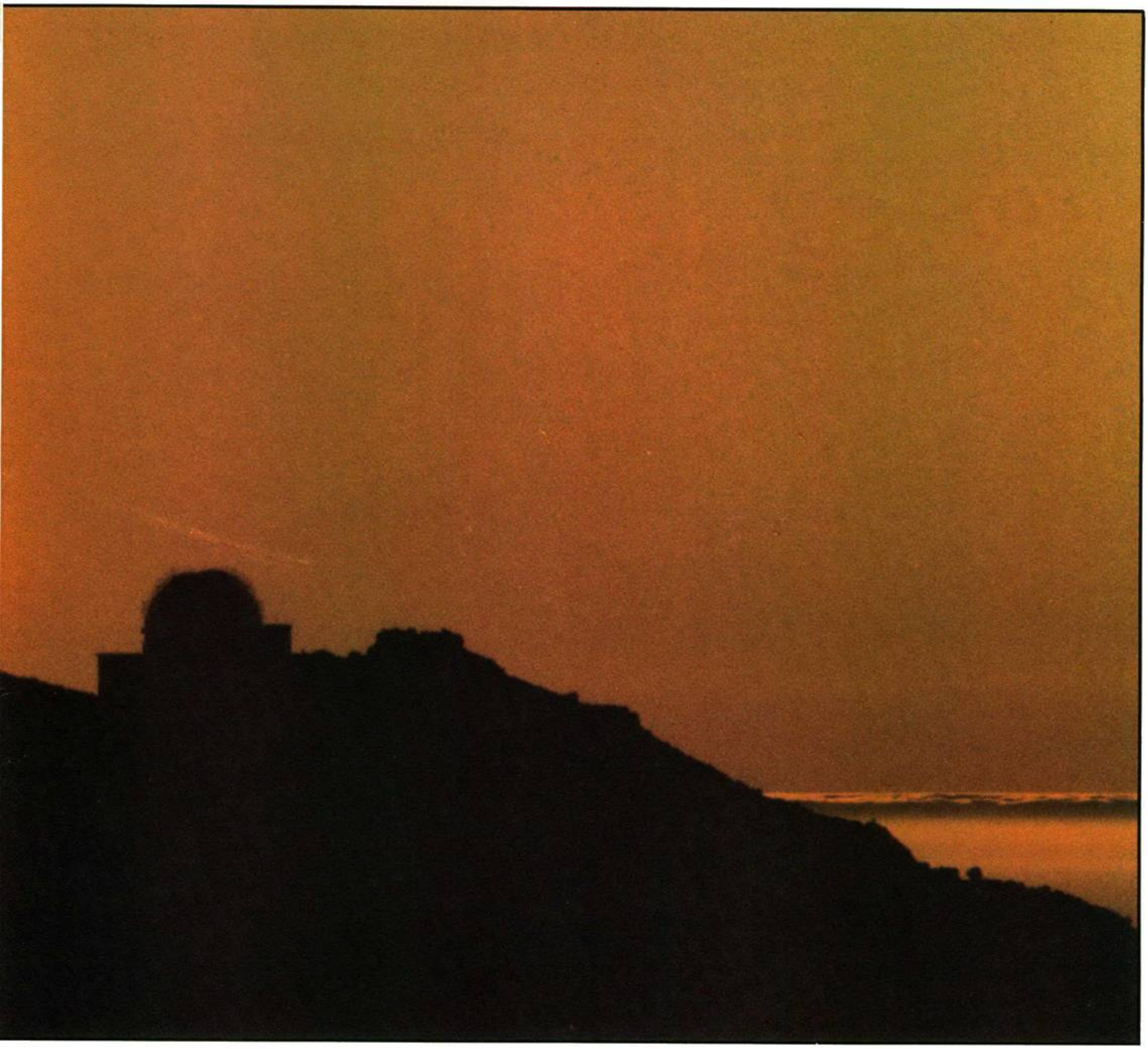
BRITISH ASTRONOMY

Reaches New Heights on La Palma

by Nigel Henbest

The gigantic radio telescope at Jodrell Bank has long been the symbol of British astronomy. And no wonder: England's weather is a national joke. But it's no joke for astronomers — cloudy skies make it a rare treat for them to actually see the night sky. Even the specially-picked site of the Royal Greenwich Observatory, at Herstmonceux Castle near the sunny south coast, has only a few nights each month when skies are truly dark and clear. So British researchers, in the main, have had to become "invisible astronomers." The pioneering radio observatories at Cambridge and Jodrell Bank tune into the longest wavelengths from the sky. A British infrared telescope, the largest in the world, picks up faint scraps of heat from newly-born stars. And England's wizards of the short wavelengths are among the world's leading X-ray astronomers. Other famous British astronomers turned even further from actual stargazing and have become front-rank theorists.

This year, however, British astronomers have begun



Silhouetted against the setting Sun, the domes of the Danish 1-meter Kapteyn telescope (left) and the 2.5-meter Isaac Newton Telescope signal new beginnings for European and British astronomy. Located on the island of La Palma in the Canaries, the observatory boasts a truly international flavor. Unless otherwise credited, La Palma telescope photos by D. Calvert, courtesy of the Royal Greenwich Observatory.

to enjoy clear views of the night sky using new *optical* telescopes to pick up the light of stars, galaxies, and quasars. These telescopes lie well away from England's unpredictable climate, perched at an altitude of 2,400 meters (8,000 feet) in the clear air of the Canary Islands. Careful testing has ensured that the summit of one island, La Palma, is among the best sites — possibly *the* best site — in the world for the optical observatory.

British optical astronomers can now complement their colleagues, and observe the galaxies or quasars whose radio and X-ray radiation has been picked up at Jodrell Bank or with the Exosat X-ray satellite. The new observatory on La Palma also means that England can retain its brightest young optical astronomers. In the past, many of them slipped down the "brain-drain," only to reappear as leading researchers at Palomar or Kitt Peak — an export achievement that did a lot for international relations, but not much for British astronomy.

The La Palma observatory will strengthen Britain's already enviable position in world astronomy — second only to the United States. Present-day historians may wish to ascribe this achievement to the country's long tradition of a Royal Observatory and Astronomers Royal, dating back three centuries; but it's more a result of the Government's "positive discrimination" in funding astronomy. All countries want to keep a hand in the big sciences, those at the cutting edge of technological and intellectual progress, but "big science" generally means "expensive science." Britain can participate in space research and particle physics, for example, only through

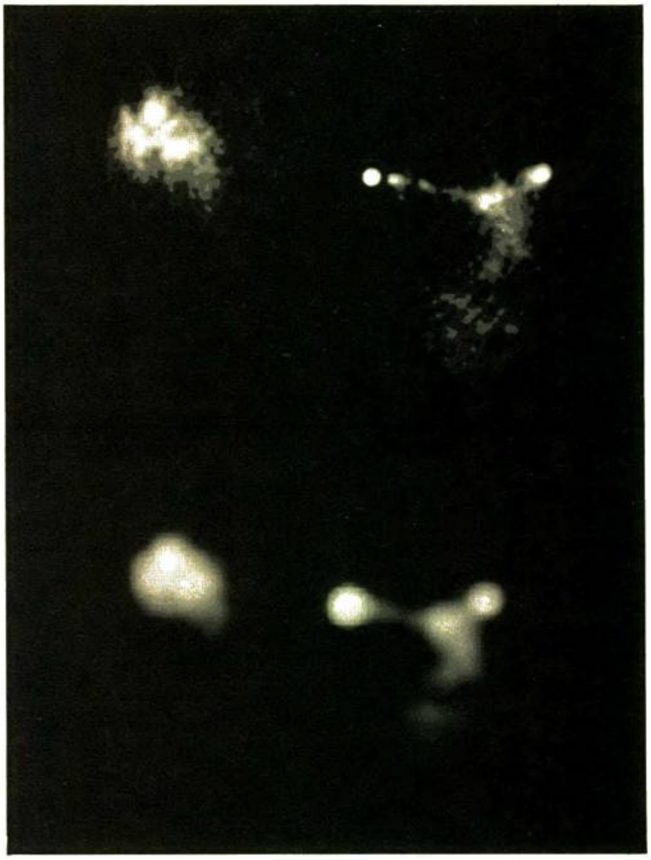
international (generally European) organizations. But modern astronomy and astrophysics have the prestige of big science while remaining affordable by a country that is no longer a superpower. It takes around $10 million to build a new instrument like the Millimetre Wave Telescope, which provides universities and industries with state-of-the-art challenges in electronics and technology, and will open whole new vistas on the universe. If $10 million seems a lot of money, consider it's a mere one percent of the cost of the billion-dollar Space Telescope or the Galileo probe to Jupiter!

Radio astronomy is the field that first made Britain's name in modern astronomical research. In the 1950s, Bernard Lovell built the huge radio telescope at Jodrell Bank to search out faint signals from space, while Martin Ryle in Cambridge took pioneering steps by linking two radio telescopes as an interferometer to resolve fine details in the radio sky. The first major results were the comprehensive Cambridge catalogues. Many radio sources, like the nearest quasar 3C 273, are still known by their listings in the 3C, or *Third Cambridge Catalogue*. Many of these radio sources lie so far away that their radiation was emitted in an earlier age of the universe. Their existence showed Ryle that the universe was changing with time, counter to the claims of the Steady-State Universe theory proposed by Cambridge theorist Fred Hoyle and, independently, astrophysicists Thomas Gold and Hermann Bondi. The famous controversy between Big Bang and Steady-State, with its immense repercussions on the universe, took place largely in their small English university town on the edge of the fens.

Ryle laid the foundations for today's great radio observatories. By connecting telescopes in pairs and allowing the Earth's rotation to swing them round, he was able to synthesize a telescope with an effective diameter as big as the length of the array. Aperture synthesis means that astronomers use telescopes far larger than any dish that engineers could actually construct. The One Mile Telescope was the first to show details within the radio sources, revealing that huge radio-emitting clouds were blasted out either side of radio galaxies and quasars. The Five Kilometre Telescope was the first to resolve radio details as well as an optical telescope can, around one arc-second. Along with its descendants, like the American Very Large Array (VLA) telescope at Socorro, New Mexico, the Five Kilometre Telescope is still at the forefront of investigating the stupendous radio output from quasars and, closer to home, the radio emission from old supernovae and regions of starbirth within our Galaxy.

The great dish at Jodrell Bank is a leading instrument for studying pulsars, which were discovered at Cambridge in 1967. It has also become the keystone of a remarkable new radio eye on the sky: Merlin. The name is an acronym for Multi-Element Radio-Linked Interferometer Network. This instrument consists of six radio telescopes scattered over the West Midlands of England. The farthest is 127 kilometers (80 miles) from Jodrell Bank itself, meaning that Merlin has a resolution 25 times better than the Five Kilometre Telescope and five times better than the American VLA. The dishes are too far apart to be connected by cables, so the signals follow microwave links back to Jodrell. Links running the other way enable the astronomers to check the telescopes and point them by remote control from the control console at Jodrell Bank.

Paradoxically, astronomers from a cloudy northern country have become experts on the skies of the southern hemisphere. Much of the credit for this goes to the 3.9-meter Anglo-Australian Telescope. Soon, two northern hemisphere telescopes — the 2.5-meter Isaac Newton Telescope and the 4.2-meter William Herschel telescope — will reopen northern skies to British observers. Photo shows the magnificent southern spiral galaxy NGC-253. Copyright © 1979 by the Anglo-Australian Telescope Board.



At a wavelength of 18 centimeters, Britain's Merlin resolves fine details in the structure of quasar 3C 179 (top) that America's VLA (bottom) cannot. Radio images courtesy Nuffield Radio Astronomy Laboratories, University of Manchester.

Merlin plays a unique role in investigating the birth and death of stars. At each of these critical times in its life, a star is surrounded by dust and molecules of gas. Molecules often emit powerful radiation as natural masers, and in regions of starbirth, infrared astronomers pick up heat radiation from the protostars themselves. Merlin can probe not only the gas which surrounds the protostar, but can also measure its velocity toward or away from us using the Doppler effect. At the end of a star's life, it ejects shells of dust and gas that again produce maser emission from hydroxyl molecules — water molecules with one hydrogen atom missing. Merlin's maps show in graphic detail the veils that a red giant sheds in the twilight of its days as it begins to strip down to its white dwarf core.

Merlin's radio eye is also looking at distant radio galaxies and quasars, and seeing the beams of energy that travel outward to feed the huge radio-emitting clouds. In much of its important work, Merlin is complementing the VLA. Merlin's huge extent means that it can observe at long wavelengths, around 73 centimeters, and see details almost as fine as the VLA working at 6 cm. The VLA is seeing radiation from very energetic electrons that the quasar must have emitted in the recent past. Merlin's view reveals the regions of slower electrons, so it is finding out what the same quasar was doing millions of years ago.

British radio astronomers are establishing a reputation in such "quasar archaeology." A new telescope at Cambridge is for the first time mapping radio sources at the comparatively long wavelength of two meters. It's already measured a speeding radio galaxy in a distant cluster of galaxies. The galaxy has left a two-million light-year-old trail of radio-emitting electrons across the sky. The new Cambridge telescope has found that the electrons at the end of the trail are 300 million years old, so the galaxy is moving at 2000 km per second — or $1/150$ the speed of light.

Going from one extreme of the wavelength scale to the other, British astronomers have become leaders in X-ray astronomy, alternating over the years with their U.S. rivals. American astronomers detected the first X-ray source in 1962, and launched the first X-ray satellite, Uhuru, in 1970. But the British Ariel V satellite found many more X-ray sources, and with better positions so optical astronomers could identify them. Many turned out to be Seyfert galaxies — nearby, tamer versions of the quasars. This energetic emission encouraged astronomers to follow up the idea that quasars contain a single, immensely-powerful source rather than a collection of supernovae or young pulsars. Their X-ray emitters worked like a scaled-up version of Cygnus X-1, a radio "star" which astronomers believe results from gas falling into a black hole 10 times more massive than the Sun. The X-ray results supported the ideas of Donald Lynden-Bell, then of the Royal Greenwich Observatory, who suggested back in 1969 that a quasar is a disk of gas circling a very massive black hole in the center of a distant galaxy. Quasar theory has become something of a British speciality since then, especially with work done by Martin Rees and his colleagues at Cambridge.

In the late 1970s, the American Einstein Observatory revolutionized astronomy by taking the first X-ray images of sources in the sky. Its successor is the European X-ray Observatory, Exosat, launched in May 1983. Britain's Mullard Space Science Laboratory has equipped Exosat with X-ray telescopes — similar to Einstein's — to take pictures of X-ray sources. They work at a rather longer wavelength than Einstein's telescope, so they "see" cooler gas (though X-ray emitting gas is so hot that cooler still means around 10 million degrees!). Exosat is studying the shells blown out by old supernova explosions, and the hot gas found in and around distant clusters of galaxies.

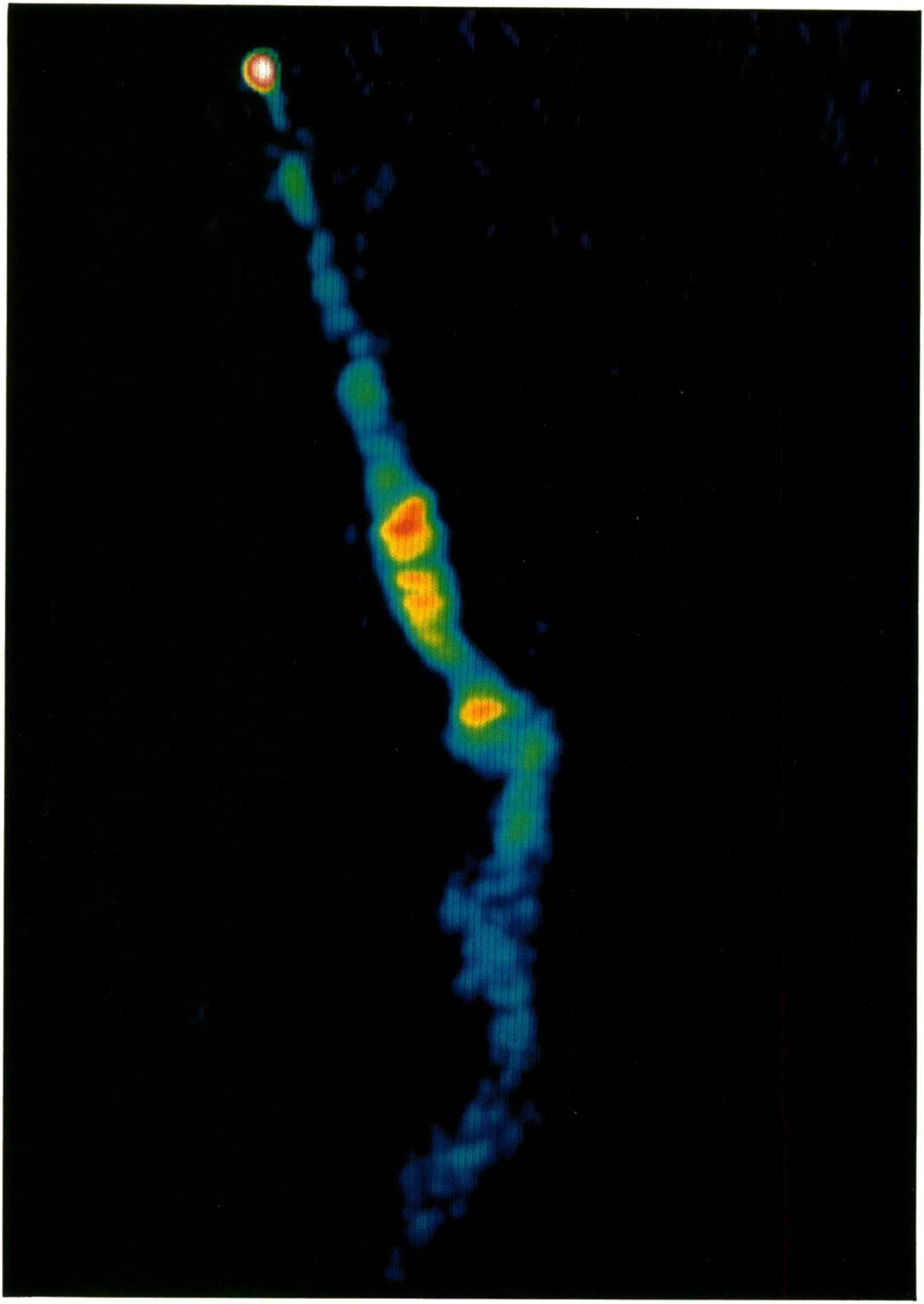
But in X-ray astronomy, images are not everything. If we had eyes sensitive to X-rays, we would find that most of the "stars" in the sky are continuously flashing, flickering, brightening, and fading on time scales from fractions of a second to months. This riot of activity arises because most X-ray sources originate in binaries, systems in which streams of gas from a normal star fall toward a compact object — usually a neutron star (a star corpse compressed to only the size of a city) or sometimes a black hole. Natural turbulence in the gas causes fast flickering, while a rotating neutron star makes the infalling gas flash or pulse in brightness. The gas generally comes from a companion star and as this star orbits in front, it regularly blocks out the X-rays.

Previous X-ray satellites were in low orbits and could not follow all these fluctuations because the Earth blocked their view for half of each two-hour orbit. Exosat is in a huge elliptical orbit that takes it almost halfway to the Moon. During each seven-and-a-half day orbit, the satellite can monitor an X-ray source continuously for up to six days; the rest of the time is lost as it swings close to the Earth at perigee. The University of Leicester built Exosat's two, large, sensitive detectors for measuring X-ray brightness. Originally, these detectors were to monitor X-ray sources as the Moon hid them and so pinpoint their precise locations; the large inclined orbit would mean that the Moon hid sources in many parts of the sky. This program should have been undertaken before the Einstein Observatory's mission. But Exosat was delayed until after Einstein had successfully measured source positions with its X-ray telescopes.

Above: At the center of the giant elliptical galaxy M-87 lies a quasar-like core. Optical photographs show a "jet" from this enigmatic object, but reveal little more than fuzzy blobs. Right: New observations with Merlin, at a wavelength of 18 centimeters, show the extraordinary resolution of the British radio telescope array. Near the core (upper left), the jet is tightly collimated, but it broadens steadily. At large distances, the jet becomes unstable and wiggles from side to side. Courtesy Nuffield Radio Astronomy Laboratories.

So Exosat's sensitive detectors are not needed to watch sources disappear behind the Moon. Instead, they are employed much more usefully in building a full picture of the activity of fluctuating X-ray sources. Exosat has found several sources where the gas streams are falling onto a white dwarf star, rather than a neutron star, and the X-rays vary as the dwarf star turns. One important example is a double star system in Perseus that flared up in a nova explosion in 1901. Exosat found that one of the system's stars is a magnetized white dwarf which spins once every six minutes.

British X-ray astronomers are now looking to the end of this decade for an exciting new telescope that will scan the skies at one of the few wavelengths so far unexplored by astronomers: "XUV" waves lie between X-rays and ultraviolet. Conventional wisdom has told astronomers that these waves are absorbed by hydrogen in space between the stars, so we are, in effect, surrounded by a galactic smog obscuring our view at such wavelengths.



But pioneering experiments on the Apollo Soyuz Test Project in 1975 and on the Voyager 2 planetary probe showed us that this smog is patchy, and we can see some stars within a few hundred light-years of the Sun. So British astronomers are building the first telescope to survey the XUV sky. It will be bolted to a German X-ray satellite called Rosat that will be launched by the U.S. Space Shuttle in 1987. Rosat will scan the sky at conventional X-ray wavelengths, while the British XUV telescope will be looking in the same direction to detect stars and nebulae with temperatures between 10,000° and 1,000,000° Kelvin.

The XUV telescope should be able to detect the hottest, youngest white dwarf stars, gas streams being swapped in close double star systems, and probably the hot outer atmospheres of some rather active normal stars — especially those plagued by "starspots." But more importantly, the telescopes may reveal new, unexpected denizens of our Galaxy.

British astronomers had the initial idea for an ultraviolet satellite that — after a history as complex as Exosat's — eventually became the International Ultraviolet Explorer (IUE). The satellite is two-thirds American; the remaining time is shared between Britain and the European Space Agency. IUE has been a remarkable success; it is still operating after almost seven years in orbit. Its spectrographs have looked at everything from Jupiter and nearby stars to distant quasars. A unique contribution to astronomy has been IUE's study of the invisible interstellar gas in our Galaxy: as light from far-off galactic stars and the most distant quasars comes through our Galaxy, the gas marks the ultraviolet radiation with dark spectral lines that tell of the interstellar gas's composition, temperature, and speed.

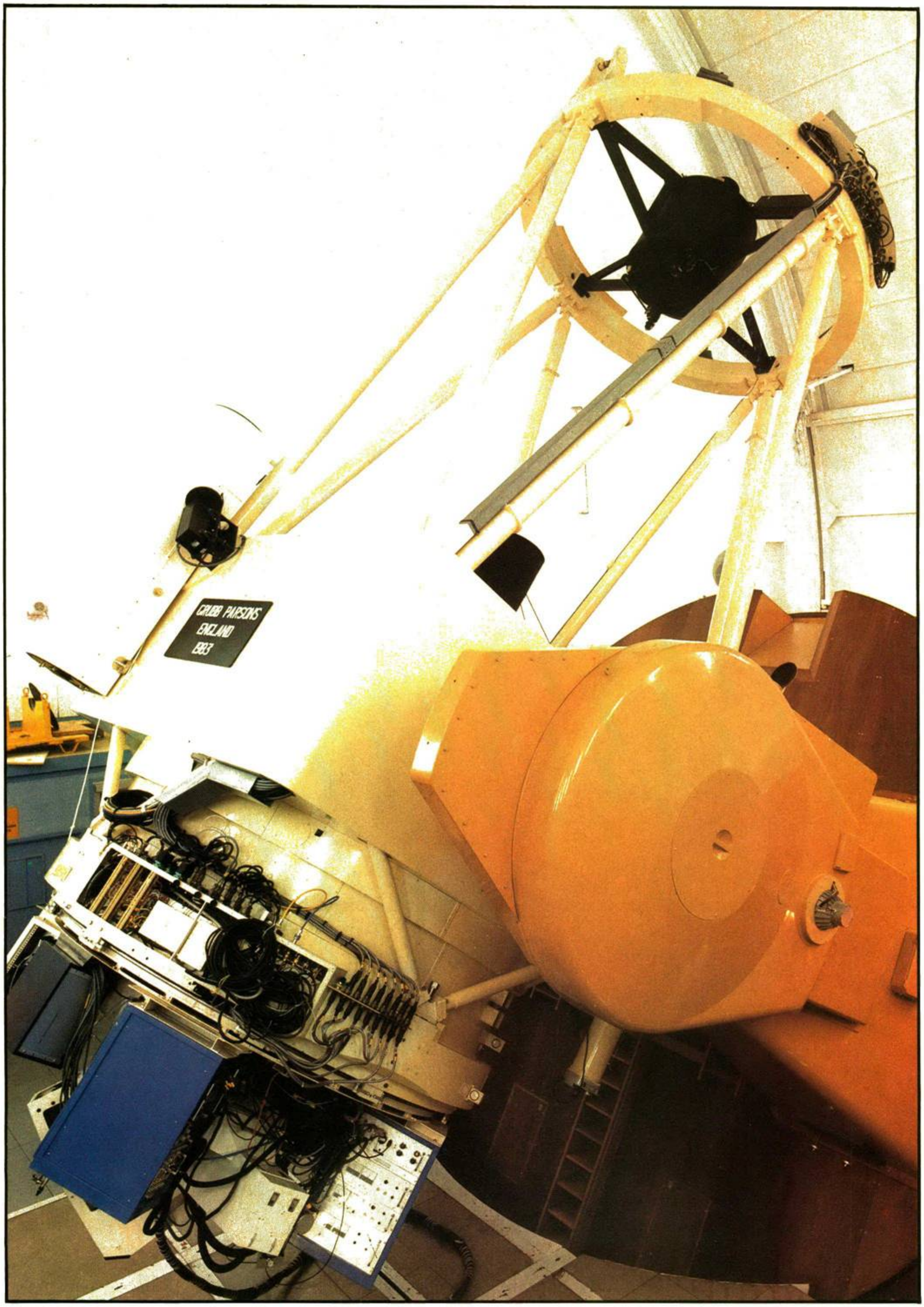
An international team headed by Michael Penston of the Royal Greenwich Observatory has recently used IUE to tie down the source of activity in the brightest Seyfert galaxy, NGC-4151, as a clue to understanding the similar

but more powerful quasars. IUE revealed three regions of gas circling the galaxy's center at different speeds. When the galaxy's tiny, brilliant core brightened, the spectral lines from the three regions responded in turn — the fastest moving after two weeks, and the slowest only after a year. This delay is presumably telling us the time it takes light to travel to reach each region, and hence their distances from the galaxy's core. Knowing the radius of each region's orbit about the galaxy's center, and the velocity of the orbiting gas, Newton's law of gravity tells us the mass in the core of NGC-4151. The answer comes out as 500 million Suns. Since this mass must be highly concentrated in the galaxy's center, it's almost certainly in the form of a black hole. These IUE observations are the most direct evidence we have that quasar activity is indeed caused by a massive black hole pulling in gas, as theorists have long been telling us.

This experience in space astronomy led to Britain's involvement in the Infrared Astronomical Satellite (IRAS). Launched in January 1983 with sufficient coolant gas for only a few months operation, IRAS was stunningly successful. In its 10-month lifetime, IRAS surveyed the entire sky at infrared wavelengths blocked by the Earth's atmosphere and found over 250,000 new sources of heat radiation — ranging from clouds of starbirth in our Galaxy to distant galaxies that emit a hundred times as much heat as light.

Although IRAS was mainly a Dutch-American collaboration, the data flowed through the control center located in the grassy downs near Oxford. There, a

This panoramic view shows the international gathering of telescopes at El Roque de los Muchachos Observatory situated in the harsh volcanic terrain of La Palma. From left to right are the Danish Carlsberg Automatic Transit Circle (in the small metal shed), the partially-constructed dome of the 4.2-meter William Herschel Telescope, the tower of the Swedish solar telescope, the half-hidden white dome of the 2.5-meter Isaac Newton Telescope, and the 1-meter Dutch Kapteyn Telescope.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1983

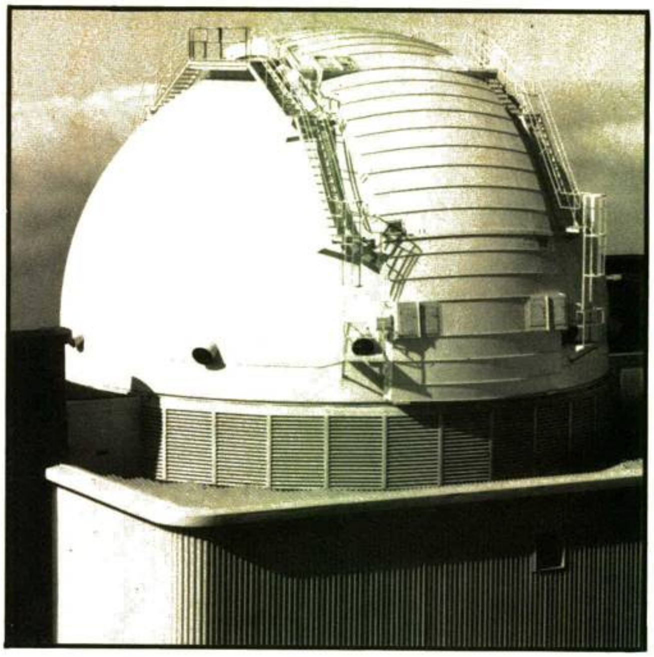
Leicester University team kept a careful watch for objects that might be moving from one scan to the next. They expected to find a few asteroids passing near the Earth, and their constant scrutiny would allow them to alert optical observatories immediately. As it happened, they discovered mainly comets. The first, which was also located by two amateur astronomers and therefore named Comet IRAS-Araki-Alcock, swept past the Earth at a distance of only five million kilometers (three million miles) in May 1983.

A later find was even stranger. Object 1983 TB looks like an asteroid, but it has the distinction of swinging closer to the Sun than any other solar system body with a known orbit — its perihelion is at only one-third Mercury's distance. Its path is strewn with a stream of tiny bodies that collide with the Earth each December to produce the Geminid meteor shower. Such meteoroids are common in the paths of comets, so many astronomers believe that 1983 TB must be the burnt-out heart of an old comet.

Astronomers need a satellite like IRAS to pick up the longer infrared rays from space, but the shorter infrared wavelengths can penetrate much of the atmosphere before they are absorbed by water vapor and carbon dioxide. So a telescope on a high mountain top can give us a view of the infrared sky, somewhat limited, undoubtedly, but a ground-based instrument is more convenient and a lot cheaper than a satellite!

With this in mind, astronomers from the Royal Observatory at Edinburgh have built the world's largest infrared telescope at the world's highest major mountain top observatory. The UK Infrared Telescope (UKIRT) has a main mirror 3.8 meters across; it was made unusually thin to reduce the telescope's weight. UKIRT is perched on the 4,200 meter (14,000 foot) peak of Mauna Kea, Hawaii, at an observatory site run by the University of Hawaii. Mauna Kea is half the height of Mount Everest, so astronomers must acclimatize before reaching the telescope or they risk suffering from altitude sickness. But such a high, dry site is the best place for infrared astronomy, and new spectrographs on UKIRT give it the ability to perform a detailed analysis of heat radiation from regions of starbirth in our Galaxy — and others.

UKIRT will soon be joined by another instrument to probe star formation. The British Millimetre Wave Telescope, which now includes participation from the Dutch, will detect the very short wavelength radio waves that verge on the longest infrared radiations. It looks rather like a radio telescope with a dish 15 meters (50 feet) across, but is far more accurately made than any radio telescope. No bumps or irregularities less than 1/30 millimeter (a thousandth of an inch) have been allowed on its surface. Special electronic detectors, already being tested on UKIRT, are needed to tune into this radiation. But the astronomers are convinced that these formidable instrumental problems are worth solving.



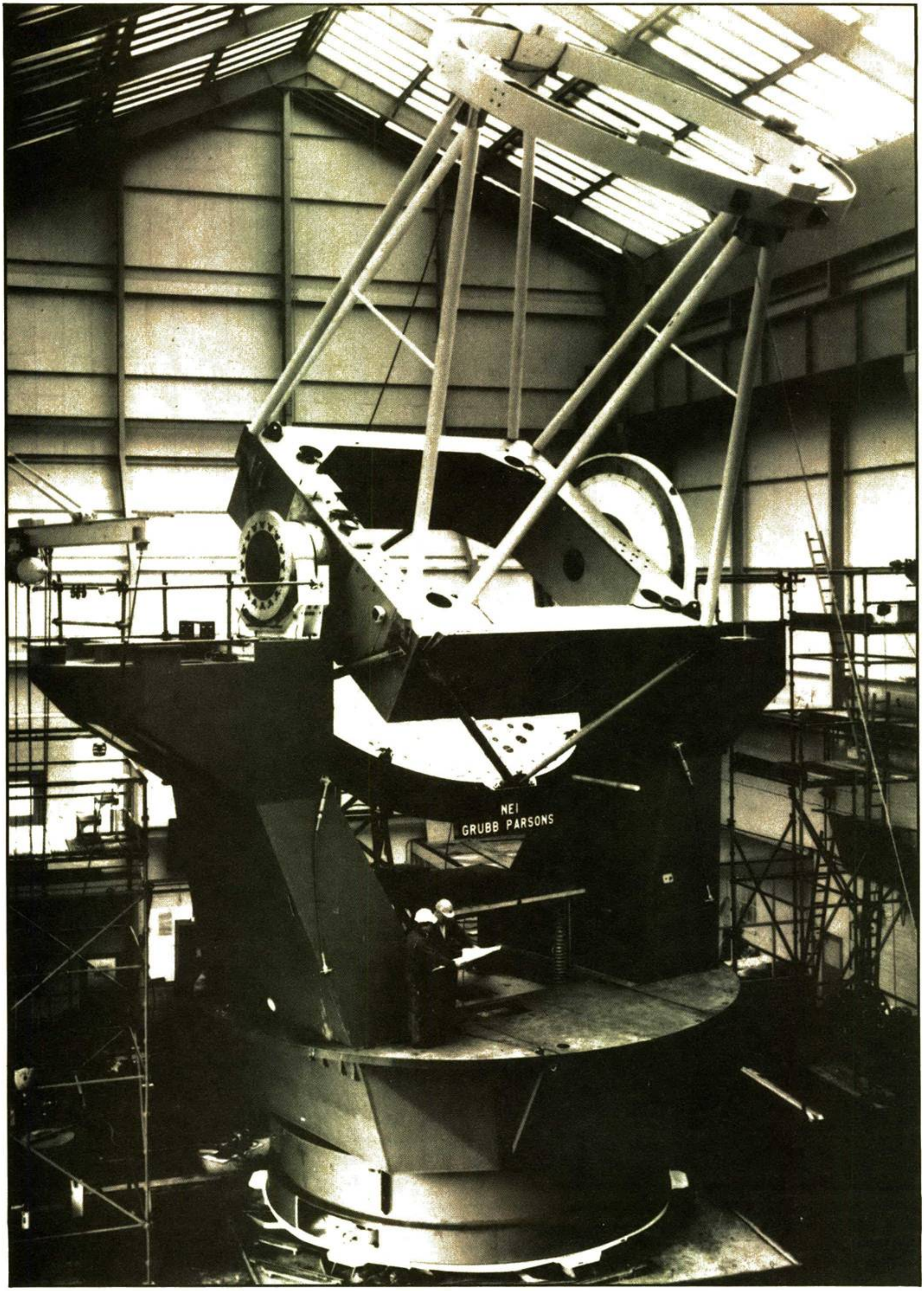
The dome of the Isaac Newton Telescope is designed to disturb the excellent "seeing" at the summit of La Palma as little as possible, while at the same time providing laboratory space and facilities to the observers and astronomers who use it.

Refurbished and transported to dark, clear, and steady skies, Britain's Isaac Newton Telescope should now honor its namesake with a steady flow of observational data. The "100-inch" aperture telescope carries several large racks of electronic instruments and a powerful spectrograph at its Cassegrain focus.

Millimeter waves are produced by molecules in space. Each type "broadcasts" on a slightly different wavelength, so individual species can be distinguished. Astronomers have already identified over 60 kinds of molecule, and this has given rise to a whole new branch of science: astrochemistry. A chemist's lab on Earth contains materials of relatively high densities and temperatures. Space chemistry takes place in a totally different environment. Densities and temperatures are very low, and important reactions may take millions of years to come to equilibrium.

Millimeter wave telescopes already operating in the United States, Spain, and Japan have observed molecules to investigate regions of star formation, and have found that this involves unexpectedly violent activity. Newly-born stars blast out fast winds of low density gas that disturb the clouds around them, disrupting some protostars and compressing gas elsewhere to form other stars. The gas flows are directed by dense disks of gas around the young stars — disks that bear a tantalizing resemblance to planetary systems in formation. Existing telescopes tell us little about these disks, for their molecules emit most strongly at wavelengths shorter than a millimeter. This is where the new British Millimetre-Wave Telescope will come into its own. Tuning down to wavelengths as short as ⅓ mm, it will probe the circumstances surrounding the birth of stars and planets.

With satellites in orbit and telescopes on Hawaii, much of British astronomy has expanded far beyond its native shores. So there's no reason why optical astronomers should remain trapped beneath grey skies. The most important spur came in the 1960s, not for any astronomical reason, but because international air travel suddenly became cheap and fast. At that time, the Australians offered Britain a half share in a joint optical telescope. Opened in 1974, the 3.9 meter Anglo-Australian Telescope (AAT) was — and still is — one of the best of these giant optical instruments in the world. The Royal Observatory, Edinburgh, built a wide-angle Schmidt telescope next to the AAT to survey the southern skies and act as a scout for the tunnel-visioned giant telescope — exactly as the Palomar Observatory had


NEI
GRUBB PARSONS

installed the 48-inch Schmidt beside the 200-inch a quarter of a century earlier.

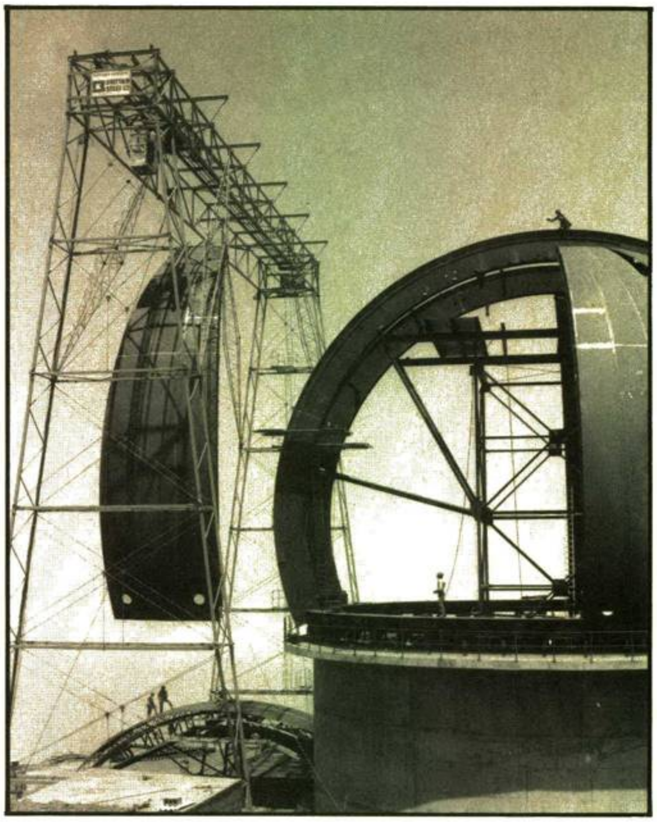
With these telescopes, British astronomy became somewhat topsy-turvy. Astronomers found themselves concentrating on southern hemisphere skies largely invisible from the British Isles. It was partly a scramble to explore little-known territory, rich with observational opportunities because they are permanently hidden from the great observatories of California, and partly a chance for astronomers to follow up southern hemisphere discoveries made from Ariel V, for example, more easily than they could look with British telescopes for optical counterparts of new X-ray sources in the northern hemisphere.

Surprisingly, though, there already *was* a large optical telescope in Britain at that time. When it was opened with a fanfare of royal glory in 1967, the 2.5-meter (98-inch) Isaac Newton Telescope (INT) was the largest in western Europe. But it suffered from a bad site; by the time of its opening, many astronomers were convinced that the INT should have been placed in a better location.

Now the transformation has occurred. In 1984, the INT resumed work after a five-year gap, during which it was moved from the grounds of an English castle to a volcanic peak in the Canary Islands. The move gave its custodians, the astronomers and engineers of the Royal Greenwich Observatory at Herstmonceux Castle, the chance to update INT's drive and computer controls to match those of the best in the world. They also provided the refurbished telescope with light detectors that are not only up-to-date, but carefully matched to use all the light that the telescope collects. The telescope also received a new mirror. The original 98-inch mirror had been cast 50 years ago as a test model for the Palomar 200-inch. Although it never gave needle-sharp images, that was no particular drawback in England. The new mirror, made of a special material called Zerodur which does not expand or contract with temperature changes, is probably the most accurate astronomical mirror in the world, surpassed in quality only by the mirror for the forthcoming Space Telescope. As a result, it gives superbly-crisp views of the sky. As an added bonus, the mirror is slightly larger, increasing the INT from a 98-inch to a 100-inch telescope.

But the most important change has undoubtedly been the move itself. English weather was, in the long run, an angel in disguise. By the time site selection was underway, astronomers had become used to traveling half way round the world to observe at the AAT in Australia. When it came time to choose a new site, they felt free to pick any place in the world. Thus, the only constraint was that the observatory should be in the northern hemisphere to complement the Anglo-Australian Telescope's view of the southern skies.

But where to begin looking with half the world to choose from? Fortunately, Lick Observatory had already been testing astronomical sites and had laid some guidelines. For a start, a major observatory must be on a mountain to get above clouds and aerosols. But the airflow over mountain ranges is usually broken up and turbulent, so that starlight coming through twinkles erratically. That may be romantic, but it blurs star images.

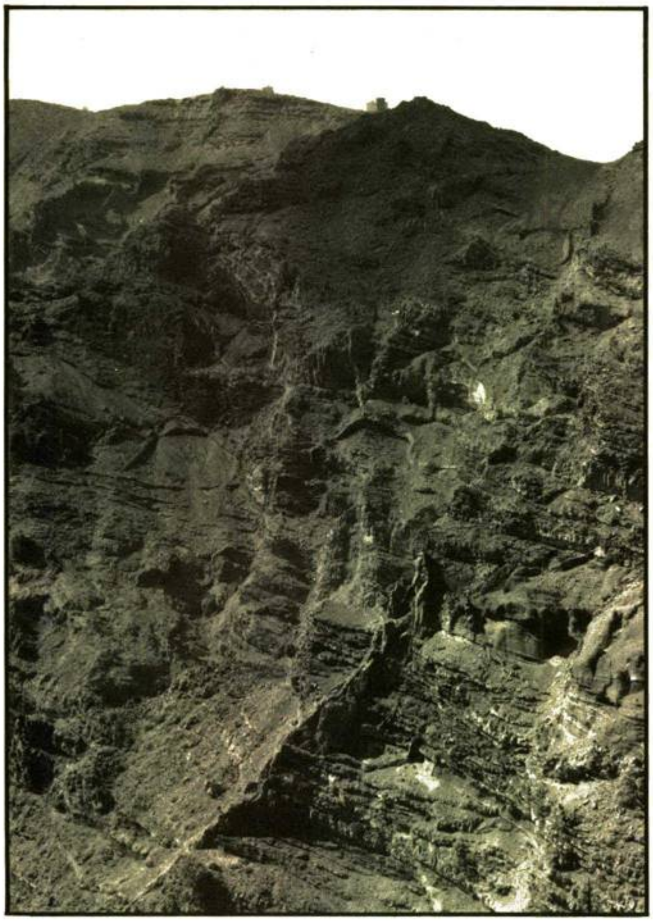


A traveling crane lifts another section of the 4.2-meter William Herschel Telescope's dome into place. The unusual hyperhemispherical dome is more compact, therefore less expensive, than the domes of other telescopes of comparable size.

Under construction by the firm NEI Parsons at Newcastle-upon-Tyne, the massive 4.2-meter William Herschel Telescope nears completion. Modern computer technology means major instruments no longer need to be equatorially mounted — resulting in lighter, faster, larger, and less expensive telescopes. The design also allows astronomers and their instruments to ride on the telescope's bearings. Workers stand on the base of the instrument's fork. The lower fork and azimuth bearing will be hidden beneath the observatory floor.

The best mountains for astronomy are smooth-flanked islands. Air moving over the sea for long distances loses its turbulence, and flows smoothly up and over the mountain top. A cold sea current offshore also helps to keep down air turbulence. This narrowed the choice considerably. The Royal Observatory, Edinburgh, sent teams of fit young men to various island peaks. On each peak, they set up a small telescope to photograph the Pole Star — to measure the amount of blurring — and check the local weather. The site testers confirmed the Lick findings: two sites in continental Europe did not look good, and they were much happier with island mountains — Hawaii, Fogo Island in the Azores, Madeira, and Tenerife and La Palma in the Canaries. The best sites were Hawaii and La Palma. The latter was nearer and more convenient, and became the first choice. As Britain negotiated with the Spanish authorities, Sweden and Denmark joined in. An agreement signed in 1979 set up an international observatory on the island.

Following the example of other observatories, it is named after the peak on which it is sited. The official name is *El Observatorio del Roque de los Muchachos*. The Roque stands 2,400 meters (8,000 feet) above sea level, and is on the northern rim of an extinct volcanic caldera. It bears a small group of rock pillars, "los Muchachos," that look like boys at play and give the site a fitting name for its international venture. Only yards from the telescope



The telescopes on La Palma are perched rather dramatically on the lip of a volcanic caldera. The domes of the 1-meter Kapteyn Telescope, the Isaac Newton Telescope, and the Swedish solar telescope are visible. The observatory stands some 2,400 meters (8,000 feet) above sea level.

domes, cliffs plunge sheer into the old crater.

The Isaac Newton Telescope is the largest at present in the observatory, and its sophisticated instruments have given astronomers a chance to check how good the Roque is for serious astronomy. They have found that it is indeed among the best in the world.

The INT's spectrograph is equipped to look at wavelengths beyond the red and into the near-infrared. Somewhat to the astronomers' surprise, the infrared absorption in this region is much less than they expected — in summer, at least, La Palma appears as good as the inconveniently distant summit of Mauna Kea for infrared astronomy.

There is another happy bonus that helps astronomers working at ordinary optical wavelengths, too. The sky is darker than at virtually any other observatory. This was partly due to the careful choice of site. Unlike the other Canary Islands, La Palma does not have beaches, so it has few of the tourist hotels, restaurants, and nightclubs that throw light upwards and brighten the sky. The observatory agreement stipulates that lights on La Palma will be kept under strict control — something astronomers at the major American observatories must envy as they suffer their skies getting brighter year by year.

But dark skies are also a result of the island's location. Earth's atmosphere has a natural glow due to excited atoms and molecules high in the upper atmosphere. The problem is worse where the Earth's magnetic field passes through the atmosphere and channels in high-speed electrons. All the major North American observatories lie near the Earth's north magnetic pole, the AAT lies near the south magnetic pole, and the large southern hemisphere observatories in Chile, Cerro Tololo, and Las Campanas lie near a dip in the magnetic field called the South Atlantic Anomaly. La Palma alone is clear of these problems: its natural airglow is only one-third as intense as that at most other observatories.

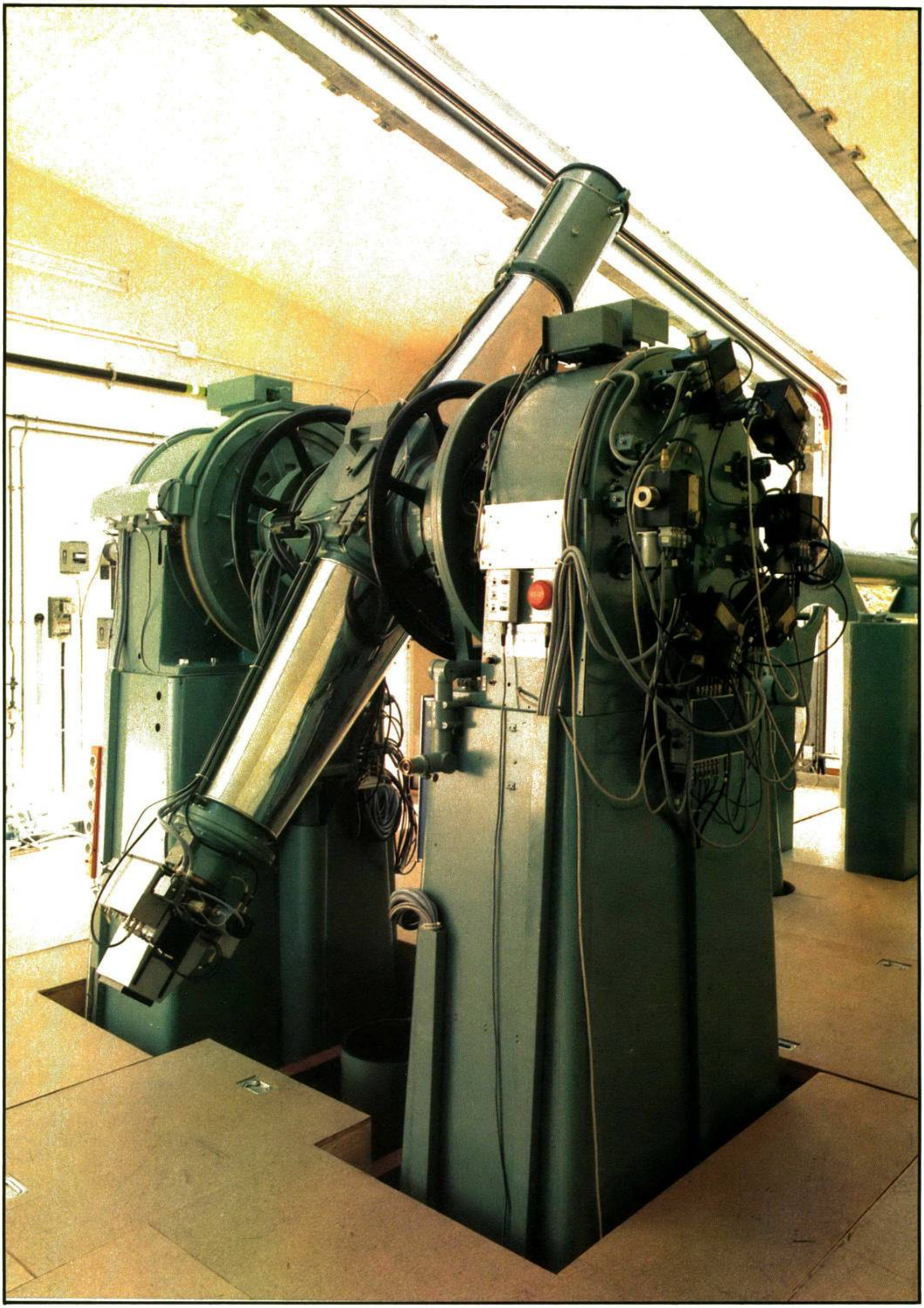
The most eagerly awaited test, however, was for La Palma's "seeing." How smooth would airflow be? How much would it blur the images? So far, the answers fully justify the choice of La Palma as the "Northern Hemisphere Observatory." As seen from most observatories, a star image is blurred to one arc-second, even on a reasonably good night, and is often two or three arc-seconds in size. But during a test run on La Palma, the worst seeing was just over one arc-second, and the *average* was a startlingly-crisp 0.8 arc-second image! Most of this blurring is due to a slow wandering of the image, so the Royal Greenwich Observatory's director, Alec Boksenberg, plans to install an image stabilizer on the telescope. A moving mirror will compensate the star's motion; the resulting stabilized image may be as sharp as 0.3 arc-second.

NASA's Space Telescope (ST) will be above the atmosphere, therefore free of atmospheric turbulence, and will certainly do better. Looking forward to a resolution of 0.1 arc-second, ST astronomers claim that it will produce images 10 times sharper than ground-based telescopes, based on the one arc-second resolution at the big American observatories. Boksenberg is delighted that the INT will attain 0.3 arc-second resolution without the complication and billion-dollar expense of placing an INT telescope in orbit.

On its new site, the INT is run in collaboration with Dutch astronomers and a smaller British-Dutch telescope has also started work on La Palma this year. The Kapteyn Telescope, named after Dutch astronomer Jacobus Kapteyn, has a mirror one meter across and is designed to take photographs of the sky covering 1½°. To do this, it uses an optical system in which the secondary mirror is spherical and there are correcting lenses before the photographic plate. Since each photograph taken with the Kapteyn Telescope will be large enough to include several bright stars with accurately-known positions, astronomers can determine extremely precise positions of everything else in the picture down to the very faintest images. This will help to identify faint X-ray, radio, and infrared sources. In the longer term, it will enable astronomers to measure how the stars of our Galaxy are moving relative to the background reference frame of very distant quasars, which appear faint in optical photographs.

A collaboration of British and Danish astronomers has given the new observatory a transit circle — a small refractor that swings north-south to measure the absolute positions of the brighter stars. The telescope, funded by the Danish Carlsberg Brewery, is called the Carlsberg Automatic Transit Circle. A computer operates the entire system automatically. It opens the slit in the telescope's

Each night it operates, one thousand fundamental stellar position measurements will stream from the Carlsberg Automatic Transit Telescope under the clear skies on La Palma. Computer-controlled operation means the instrument is not only faster and more accurate, but also that data from the telescope is more homogenous and reliable.

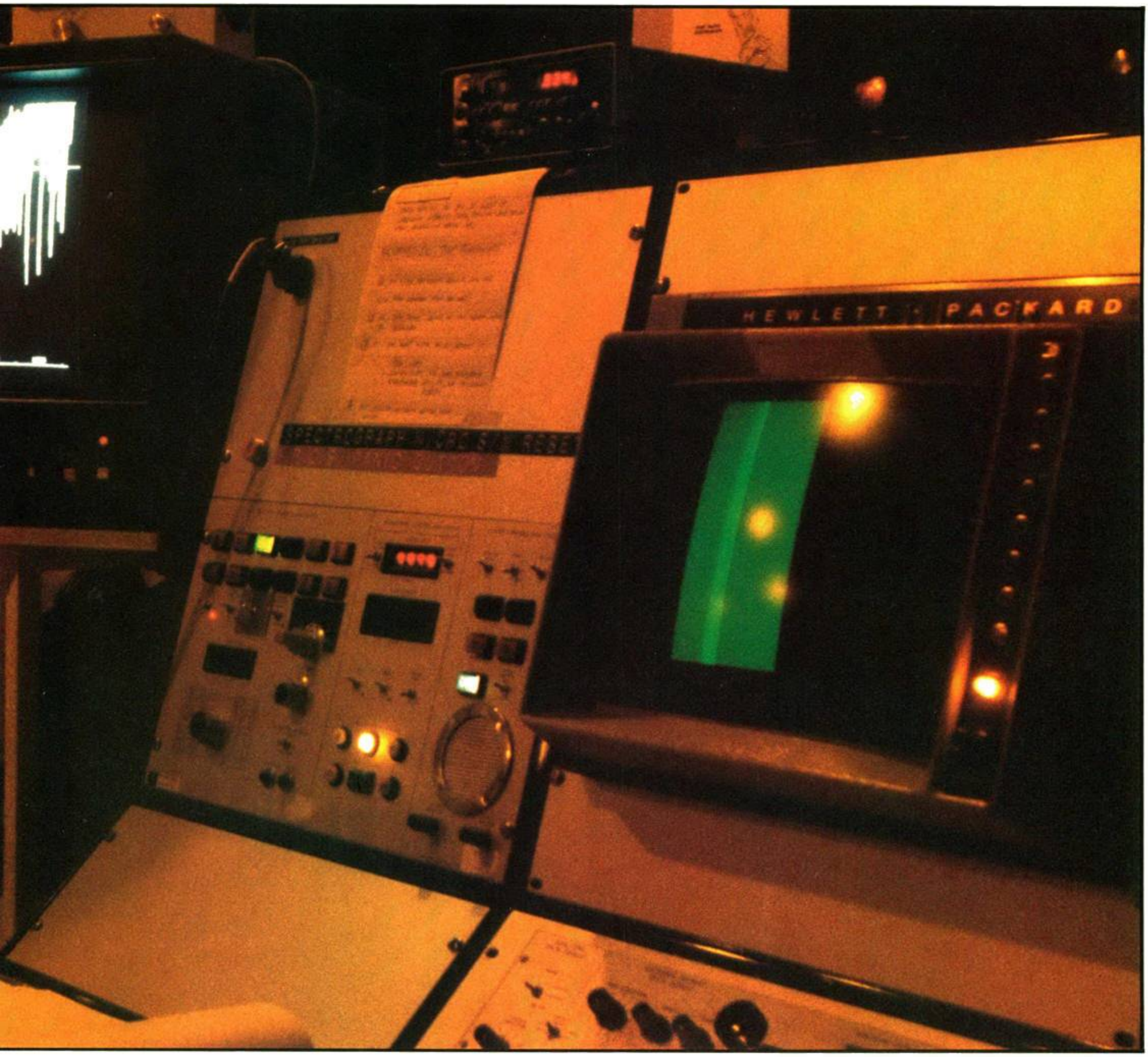


housing, points it to the approximate position where a star should cross the meridian (north-south line), takes in the signals from the electronic detectors that "see" the star, and computes the star's actual position correct to 0.2 arc-second. The whole procedure takes only 30 seconds, so the telescope can measure the positions of a thousand stars every night. Over the years, the data will keep star catalogues up to date, and the observations will tell us more precisely just how the stars near us in space actually move.

Swedish astronomers have two telescopes on La Palma. One is a 60 cm reflector that measures star brightnesses through filters that pass only a limited range of wavelengths. This technique, devised by Swedish astronomer Bengt Stromgren, tells quickly and simply a star's temperature, the mix of elements in it, and how much of its light has been absorbed by dust in space. The second Swedish instrument is a solar telescope — a refractor fixed vertically in a tower with a moving mirror at the top, which swivels to reflect the Sun's light down the telescope tube. The telescope projects the Sun's image into an underground laboratory beneath the telescope. The 20 cm test lens has already produced excellent results, and Swedish astronomers are planning to increase these by replacing it with a lens of twice the aperture.

The Spanish have no telescopes of their own on the Roque, but they earn a 20% share of the time on all the other telescopes in return for providing support services at the site. The Spanish have installed and maintain power and telephone lines, and are building a *Residencia* where astronomers can relax, eat, and sleep during the day. They have also constructed an access road from the island's main town, Santa Cruz, up a volcanic slope so steep and irregular that many visitors thought it couldn't be done at all.

Currently rising in the midst of the observatory is a new, circular, concrete structure nicknamed the Coliseum. It is the base of the dome for the observatory's main

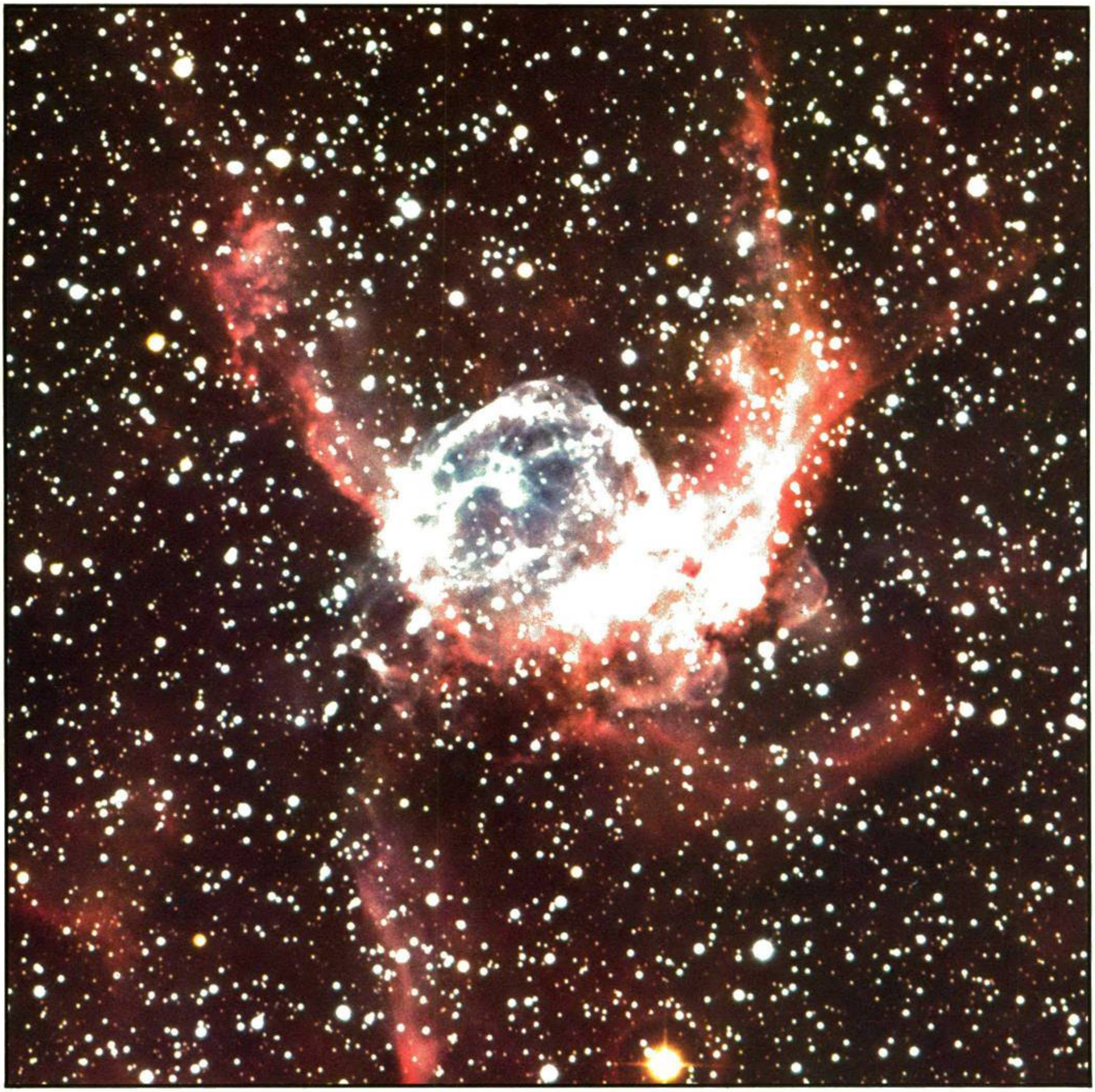


In from the cold, astronomers can run the Isaac Newton Telescope entirely from its control room on La Palma — and eventually from a control room at the Royal Greenwich Observatory in Britain. The jagged white line on the center screen is a graph of intensity versus wavelength — a spectrum — from the telescope's Cassegrain spectrograph. Other screens show the instrument's status and optical configuration.

instrument: the William Herschel Telescope. This new telescope will be the world's third largest when it goes into operation. Its primary mirror is 4.2 meters across and made of a low-expansion, glass ceramic called Cervit. Even in the early stages of planning, astronomers at the Royal Greenwich Observatory expected the William Herschel would better its near twin (the AAT), would outclass the Soviet 6-meter with its inferior glass mirror, and rival the Palomar 5-meter (200-inch) now suffering from light-polluted skies. The superb results so far produced by the Isaac Newton have raised hopes even higher. The INT is turning in results every bit as good as the AAT, though its mirror is only two-thirds the size. If the Herschel Telescope keeps up the trend, it could prove to be the best in the world — if not the largest.

Other telescopes are bound to come to the Roque de los Muchachos now that the site is "tried, tested, and approved." A consortium of Nordic countries — Sweden, Denmark, Norway, and Finland — is already planning a 2.5-meter telescope for the observatory, and Italy is testing the Roque as a place for its long-planned 3.5-meter reflector.

Other innovations are underway, too. With air fares increasing and telecommunications becoming cheaper, it is now quite as sensible to control a telescope over telephone lines rather than fly out an astronomer in person. In 1982, astronomers in Edinburgh made the first intercontinental remote observations with the U.K Infrared Telescope on Hawaii. The Royal Greenwich Observatory has now obtained direct pictures from an optical telescope at Kitt Peak in Arizona. British astronomers soon expect



Using the 3.9-meter Anglo-Australian Telescope, British astronomer David Malin obtained this photographic record of a Wolf-Rayet star's history of violent outbursts. The star has ejected gas, forming the bluish shock-front "bubble" on impact with surrounding interstellar material. Copyright © 1979 by the Anglo-Australian Telescope Board.

to control the INT in La Palma on a regular basis from a duplicate control room in medieval Herstmonceux Castle.

Britain's small size means that its astronomers are used to working together no matter what wavelength they study. This close collaboration has led to their installing seven identical computers at major astronomy centers. The Starlink system has a common set of programs that allow astronomers to manipulate views of the sky as seen at any wavelength — whether obtained at radio wavelengths by Merlin, in X-rays by Exosat, or in the optical by a detector on the INT. If the image data is a photographic plate, Ed Kibblewhite at Cambridge has built the world's fastest laser scanner to turn information from a photograph into digital data for computer analysis. Or an astronomer can use Starlink to analyze spectra from IUE or UKIRT. Astronomy is now very much an international subject, and is becoming increasingly so. With multi-national collaborations in satellites like IRAS and in ground-based observatories on the scale of La Palma, the future clearly lies in cooperation. Yet amongst this, British astronomers feel an element of insular pride that they still play a major role in this one particular science — a science which is literally the biggest of them all.

Nigel Henbest is a freelance astronomy writer, author of The New Astronomy *(with Michael Marten, Cambridge University Press, 1983) and eight other titles. He took his B.Sc. in astronomy and physics at Leicester University, and his M.Sc. in radio astronomy at Cambridge University. Henbest is astronomy consultant to* New Scientist *magazine, and public relations consultant at the Royal Greenwich Observatory.*

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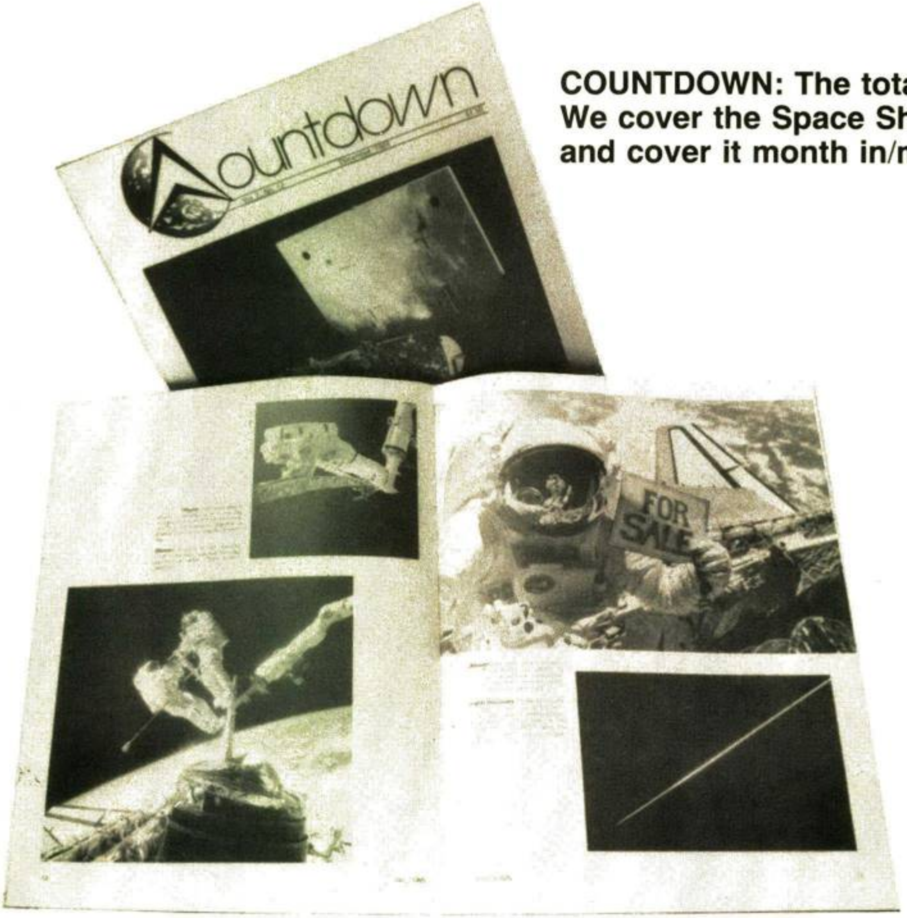

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ASTRONOMY Forum

Chasing the Ogre

Every amateur astronomer hopes to make a contribution to the science of astronomy. Through dedicated observing or careful record keeping, some of us are fortunate and find new comets or novae, or our observations of variable stars provide astronomers with data required in their work. I had long hoped that my years of meteor observing would turn up a new meteor shower or capture a fireball on film to aid meteorite recovery.

As a media consultant and researcher ("Media research by day, meteor research by night" is my motto), I have been fortunate enough to experience the "eureka" experience — the thrill of uncovering something new — more than once. And with each discovery, the feeling that overcomes me is indescribable.

But as a researcher, I am aware of the devious nature of the universe. It is a circuitous course with deadly pitfalls, dead ends, and bad luck (as well as good) strewn in the path of the credulous observer. So it is hardly surprising that in seeking a meteor shower, my observing buddies and I should instead find a new type of variable star. The coincidences and twists in the story are a good example of how Mother Nature works.

For the last four years, Kai Millyard, Bruce Waters, and I have watched major showers together. We've recorded our observations on tape and worked up the statistics on each shower. While I specialize in meteors, Kai prefers deep-sky objects (particularly planetary nebulae), and Bruce enjoys variables. It is curious that the object we found looks like a bright point meteor when it flashes, therefore it's a variable star of some nature and may be associated with a nova. (If you'll bear with me just a little longer, I'll tell you what we found. Please . . .)

Kai, Bruce, and myself must have been among the few people who bothered to watch the Perseid meteor shower peak last year under the Full Moon. Despite the brightness of the sky and intermittent clouds, we managed to log 200 meteors in a five-hour period. A solid cloud front finally started moving in, so we turned east to squeeze in a few meteors before we felt done in. We were rewarded with a brilliant flash of white just above the Pleiades, the last "meteor" of the night.

Two weeks later on Labor Day weekend, the three of us traveled north of Georgian Bay to take in the marvelously dark skies of northern Ontario. Having driven five hours to get to the site, we managed a couple hours of meteor observing before tiring out. Driving back to our campsite, we stopped at a lake to photograph an aurora. While we walked up the beach, we noticed the Pleiades had risen and we decided to test the sky darkness by counting the cluster stars. As we did this, a zero-magnitude flash went off a few degrees above them.

Recently, I had proposed that a good way to detect new minor showers would be to map the odd "point" meteors one sees — meteors that do not seem to move because the observer sees the trail head on — so I noted the position of the flash and asked Bruce to do the same. Comparing notes, we both placed the position as coinciding with a fourth-magnitude star in Aries.

Then Bruce reminded me of the observation we'd made two weeks before on the night of the Perseids. We realized the two flashes were in about the same place. After a much needed night's rest, we considered the observations further and tried to recall if we had seen any bright meteors diverge from this apparent radiant on other occasions. We came up with another bright point meteor seen on July 28 while monitoring the Delta Aquarids.

But something was peculiar. The odds of seeing three bright point meteors but no diverging meteors from a radiant are slight. If the point meteors had been faint, we might have assumed the diverging meteors were there but were too dim to be noticed. The points we had seen were bright, however, so we should have noticed a few diverging meteors.

But they just hadn't been there.

The apparent non-motion of the radiant as defined by the three flashes was even more troubling. Meteor shower radiants appear to change position among the stars from night to night as the Earth moves through space, so there is no such thing as a stationary radiant. Though we had not plotted the first two flash positions as accurately as the last one, the expected motion should have been far greater than our margin of error.

Over the next month, I mentioned our three observations in correspondence with various meteor observers, asking if they had noted any activity possibly related to the apparent radiant. I eventually received a letter from Mark Zalcik in Edmonton which contained two interesting bits of information. Knowing the position, he had watched it and caught a zero-magnitude flash within two hours. More intriguing, he had just read that Brad Schaefer of NASA was gathering observations of "bright point meteors" and that Schaefer thought such flashes were of stellar origin.

I had met Ken Tapping of the Herzberg Institute in Ottawa at the North York Astronomy Association (NYAA) Starfest in August, so I gave him a call and asked if he knew of Schaefer's work. If we hadn't impressed the professionals at Starfest with our observing experience, I'm sure we would have been brushed off

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— and that would have been the end of it. As it was, Ken took down the details and promised to let us know anything interesting.

I was extremely surprised when he called back just two hours later, notably excited. While no one at Herzberg knew of Schaefer's work, one of the theorists wondered if the flashes might be related to gamma ray bursters. Gamma rays had occasionally been detected by satellites and other detectors, but they were very short flashes. As far as the researchers knew, the bursts had never been pinned down to a specific object because of the low resolution of the X-ray detectors and the apparent randomness of the bursts. Certainly no one had ever reported seeing the theoretically-predicted visible flash that might accompany a gamma ray burst.

Ken advised us to monitor the location and, if possible, obtain a picture as evidence and to determine the precise position. We organized a concerted effort to watch for flashes. I called several groups in Ontario, asking them about previous observations or pictures and enlisting their help to monitor. I cabled Mark Zalcik in Edmonton, advising him of the possible significance of the object and his observations.

That night, October 18, I raced ahead of an incoming weather system and set up outside a provincial park 150 miles east of Toronto. As predictably as clouds arrive, a policeman drove up just as I had set up and asked what I was up to. I thought of being direct and explaining that I was there to photograph the sky all night hoping an unheard-of object would flash for a tenth-of-a second, but figured the group couldn't raise bail. Instead, I pulled out an official-looking NYAA membership card (which up to that precise instant had never had a function) and explained that I was going to shoot the lovely aurora that had just sprung up. Thinking the NYAA was some professional, licensed association (thank God we had not called it a *club*), he apologized for disturbing my study and disappeared.

I set up my camera to catch the area and started a time exposure while monitoring the sky for meteors. Almost two hours later, I had a nice meteor total and several pictures of star trails uninterrupted by fireballs or flashes of any sort. I let my eyes meander around the area, enjoying the stars, the Milky Way, and the odd meteor. Then I saw a dim orange point meteor. Like a fisherman, I thought of throwing the runt back, but having begun to record such meteors' positions, I surveyed the area to determine its precise location. Then my hair stood on end — I realized I had lost my bearings and the flash was directly on the fourth-magnitude target star! Could the beast have taken on a different color and brightness? And what were the odds of a point meteor being right on the star? I immediately dismissed the possibility of having imagined it, since I was not concentrating on that star and one simply does not make up colored glitches. I realized the camera was on and quickly turned it off.

During several more hours of observing, no further flashes occurred. I made my way home and dropped the film off for developing the next morning. Later, I picked up the photos and immediately flipped to the sixth shot on the roll. Nothing. I was disappointed, but looked through the prints to see if I had caught any meteors. The seventh shot had something, but not a meteor — it was a point beside three nearly equally-bright stars which formed a right triangle. Right shape, right brightness, and a point next to the right-angle star. I hurried home and called Ken in Ottawa, then called the International Astronomical Union (IAU) to report our four observations, Mark's sighting, and the photo.

But we were embarrassed by our riches. Why, I was asked skeptically, did we have so many observations while no one else had reported anything at all? I replied it was a matter of quantity and quality of perception. Since my group and I observe with the naked eye far more than do most observers, we would have more chances to see a random flash. While anyone could see it, untrained viewers would probably ignore it and experienced observers may take it to be a meteor.

The next day, the NYAA went north for a deep-sky weekend. We observed all night and shot lots of pictures — with no results. Saturday it rained. While talking about the object over dinner, I realized that other objects like it probably existed but were less noticeable — and that my records on thousands of sightings would be a good place to start looking for these. Then I remembered a bright point meteor seen months before that had seemed very close, if not coincident, with a star.

I drove to the village and called Bruce, asking him to advise Ken of another position to monitor. Bruce was subdued. He said we should pin down the first object before going on to others. But our picture, I reminded him — what more is needed? I nearly sank through the floor when he gently explained that the shot had missed the target area. But the triangle and the point match the area, I argued. He had matched the shot to three fourth-magnitude stars (our area contained two fifth-magnitude stars) arranged in the same shape, which covered the same amount of area. The point was a photographic flaw. Einstein said, "The Lord is subtle, but not malicious," but I really wonder when it comes to the twists one has to negotiate in the scientific process. I had misaligned the camera because I couldn't see the target properly through a very dark screen, so instead caught a group of stars that looked like the target area.

It was mortifying to find I had reported a worthless picture to the IAU — I thought I had totally blown our credibility. The next two cloudy days seemed very long. On Tuesday, one of our group members came up to look at a scope I was selling. We stepped outside and I suggested he train it on the Pleiades to get an idea of the instrument's field of view and image quality. Since the Pleiades were playing tag with clouds and were quite low and dim in the city, I sought to identify their position through binoculars. Within seconds of searching, I saw . . . (of course) a flash! Riveted to that position, I saw no evidence of light from a plane or star and ascertained the position was near our target star. But considering we had just stepped out and my eyes were still adjusting to the dark and binoculars, I dismissed it. Actually, I did more than that — I looked at my watch and made a mental note: "9:42 p.m. Gone crazy."

We spent some more time catching various objects in the scope, then came in and put together the instrument's various components for the buyer. Bruce called, saying this object of ours was driving him to distraction. What's the problem, I asked, having forgotten about my own "observation" during the last hour. He said that he was studying all night and couldn't observe, but he must have been jumpy because when he got up to close a window, he thought he saw a very bright flash when he momentarily looked out and noted clear sky in his area. Hesitantly, I asked him what time this happened; he replied that it was 9:41 at the time. Comparing our watches for synchronization, his was a minute behind mine. This is ridiculous, I thought — but interesting.

To date, we have 14 observations of bright flashes in Aries. Most have been placed coincident or just next to the target star. One binocular observation places it at the position of W Ari, an irregular variable star which ranges in brightness from ninth to 13th magnitude. W Ari is also known as Nova 1855. This star was first brought to our attention by Doug Cunningham when we phoned him on October 18 to ask his group's help in monitoring.

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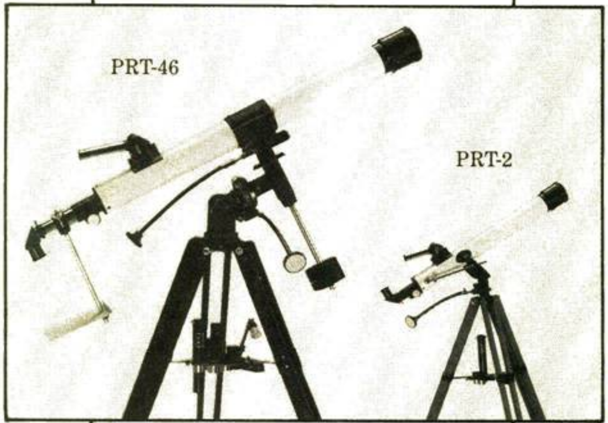

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Observations have come from Edmonton, Halifax, and various locales in southern Ontario. Since all sightings place the flash in the same area, this rules out reflections from an Earth-orbiting satellite. Unfortunately, bad weather has prevented us from obtaining a photograph. We have shot over a hundred hours without catching anything, but then again, no bright flashes have occurred during photography. One night, I had just turned off the camera to let a cloud pass when a −1 magnitude flash went off next to the Pleiades. "Thank you, Mother Nature," I intoned, muttering choice words in various languages.

I soon realized that the flash was on the wrong side of the cluster and later traced the Taurid meteor radiant to that very point. This is the closest any shower came to our target area in the past months, so it is unlikely any real point meteors cluttered our observations. Another picture taken when a third-magnitude flash was seen revealed a large point in the position of W Ari. This time the field was correct, but the point turned out to be the only such flaw in the entire roll.

Brad Schaefer, the NASA astronomer who reported in the December 24, 1981 issue of *Nature* an optical counterpart of a gamma ray burster recorded on a plate taken in 1928, told us that no gamma bursts have been traced to our area. A more recent scientific paper in the November 1, 1984 issue of *Nature* describes three observations of eighth-magnitude flashes in an area of the Large Magellanic Cloud from which gamma ray bursts had previously been detected — and gamma rays were not simultaneously detected there. Thus, it is still possible that our star is a gamma ray burster.

More recently still, the November 1, 1984 issue of the *Astrophysical Journal Letters* contains four very technical papers on gamma ray bursters, including two new optical detections made by Schaeffer on plates taken in 1901 and 1944. Those old Harvard plates sure have been a gold mine for modern astronomers!

In the meantime, we're waiting — hoping this thing is real. Kai is currently in Chile doing an observing run for the University of Toronto. While he's there, he plans to take a spectrum of W Arietis in the hope it will turn up peculiarities related to the flashes. We continue to monitor our star visually and photographically whenever possible.

Being an advertising man and a bit of a punster, I have coined a term for visual objects of this nature that may be easier to use than "a bright point flash that looks like a meteor." Considering the unpredictable nature of these objects and the stellar mythologies of giant and dwarf stars, I call it the "Ogre." Should it turn out to be related to gamma ray bursters, the name is an acronym for Optical Gamma Ray Emitter — or, more pertinent for us amateurs, an *Observable* Gamma Ray Emitter. Since gamma rays may arise when a dense dwarf star pulls away the extended atmosphere of a giant stellar companion, which then falls on the dwarf's surface at relativistic speeds, this nickname seems appropriate. The true nature of the beast remains to be seen.

Bill Katz
Og's Bog Observatory
Willowdale, Ontario, Canada

The Armchair Observer

Frigid air bites your face. Your fingers go numb as you struggle to focus on a dim and distant speck of light centered in the eyepiece. You cover your mouth and nose with a scarf so as not to fog an ice-cold eyepiece. The image drifts out of focus as your eyes dribble tears. Sound familiar?

Tonight's skies are crystal clear. Stars sparkle like diamonds on black velvet; the air is cool and crisp. I could be outdoors, my eye glued to the eyepiece relishing some distant orb — but instead I am sitting in my favorite chair. A large fire crackles in front of me and the sounds of Chopin fill the air. The floor around my feet is strewn with books and charts, including *Burnham's Celestial Handbook* and Vehrenburg's *Atlas of Deep Sky Splendors*.

Observing? I have it all, for I am what is known as an "armchair observer" — a special breed not understood by many.

Every year, reams of new material are written about the pleasures and techniques of observing, proper cold-weather wear, new films and equipment — the list goes on and on. Amateurs keep building larger or more powerful telescopes, manufacturers come out with better and bigger products, and today's more sophisticated equipment produces observatory-quality photographs.

In short, the hobby of astronomy has mushroomed into a highly technological and perilously expensive pursuit.

Yet the Glass Giant of Palomar has spent its finest hours in my service; the 48-inch Schmidt telescope is at my beck and call. Bok's *The Milky Way* and Ferris' *Galaxies* bring me the fruit of the world's best telescopes. Neil Armstrong explored the Moon for me; the Viking Lander transmitted the martian Plains of Gold to my living room.

I can always find an excuse not to take my like-new, hardly-used, 8-inch Schmidt-Cass off the shelf. Believe me — I have tried to use it. But after half an hour of suffering, I'm ready to pack it up. I get bug bites head to toe in summer and frost bite on the fingertips in winter. Spring and fall? Every season has its drawbacks. So I have retreated to the den where, sipping on a glass of sherry with my feet warmed by the fire, I can explore the wonders and mysteries of the universe. Whether I'm using the full aperture of photographs or the great magnification of the written word, I can see across — no, more than that — transport myself across the solar system, or with equal ease the universe.

My imagination is not hampered with vibrations, unstable mountings, poor seeing, or missing dewcaps. Come to think of it, there are very few drawbacks involved in my style of astronomy. Some people argue that half the pleasure of astronomy is derived from observation, splitting elusive doubles, catching glimpses of the spiral structure in M-33, or seeing glints of sunlight from the polar caps of Mars. Some of you build your own telescopes, or have tried your hand at serious research. You use your equipment almost nightly while mine sits neglected on a shelf wrapped in its dust-proof plastic bag, patiently waiting the chance to digest some starlight. I don't miss it.

My love affair with astronomy goes back some 25 years, and what a love affair it has been! I anxiously await the arrival of ASTRONOMY and *Sky & Telescope* each month, and devour them cover to cover. My library is extensive: ranging from books that were published in the eighteenth century to those published last week. I keep maps, charts, and slides at my disposal, ready for use without the need of traveling to a dark site, setting up, and suffering the indignities of polar alignment.

Tonight I plan to journey to the Great Nebula in Orion to explore once more its delicate clouds and wispy tendrils. I'll probe the mysteries of stellar evolution, and in my imagination dwell for a while on a small world basking in the glow of a young star's life-giving warmth. This is the realm of the armchair observer.

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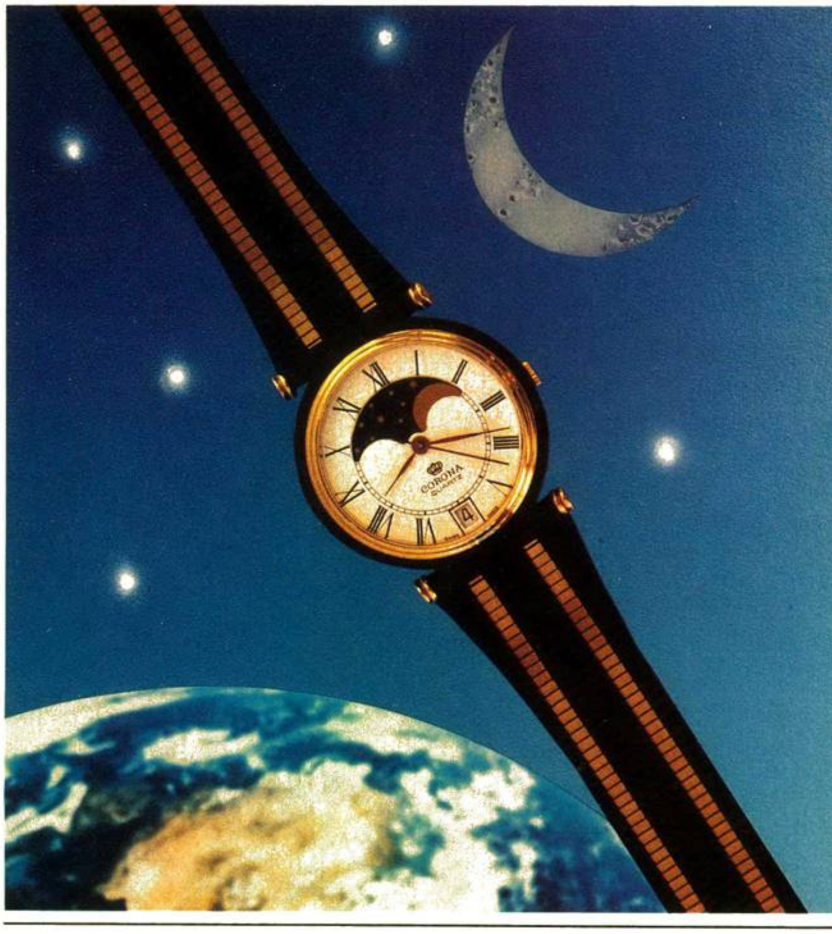

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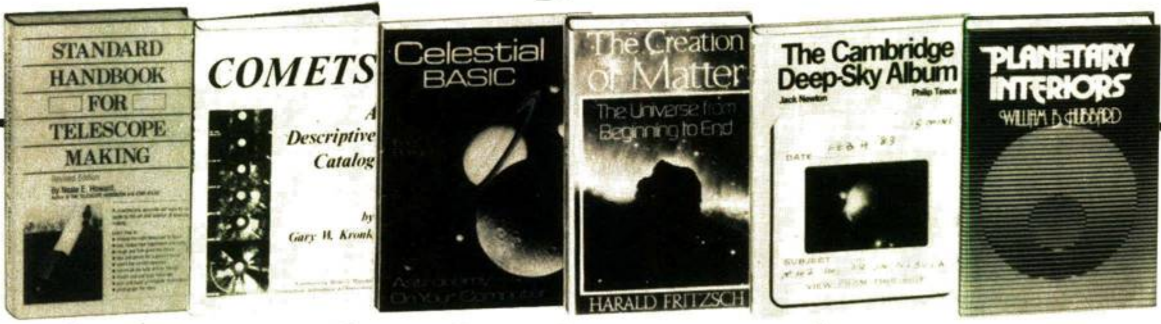
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Astronomy 4/85

ASTRONOMY
In Focus

Howdy, y'all!

Dear Enlightened Ones / Well, ominous 1984 is almost oblivion and the season for horrendous holiday hoopla is upon us. In that vein, we send y'all photo greetings from the home office of Decadent Astronomers International in mythical Cody, Wyoming.

We've had a busy year.

Firstly, in January '84 we lined up all nine planets around the campfire for the traditional "every fourth century" family reunion photo.

Nextly, we initiated a new member this year, Mr. Ed Leikam, Esq. There are now three Decadent Astronomers — up 50% from the year before. (Even The Planetary Society couldn't swell its rolls that fast!) For his initiation rites, Ed had to fly to Morocco, get a bona fide moontan under the annular eclipse, and then buy us all drinks in Paris afterwards. We passed out under our space blankets in the sculpture garden at the Louvre. Now that's decadence. (Okay, the real reason for camping there was that the cheapest hotel room available in Paris that Saturday night, June 2nd, was a mere 1200 francs — *only* $150 — due to the fact there were 10,000 ex-Allied WW II vets in town for some D-Day reunion.)

Finally, as the photo shows, we undertook a massive capital building program at our Upper Greybull River Observatory — now the finest astronomical observatory of its kind anywhere in the known universe. We built a 10-meter psychic telescope around the main observatory structure. If you think it resembles an astronomical medicine wheel, you're on the right track. It was carefully aligned and calibrated, and is now in perfect psychic resonance with Jupiter, Saturn, Easter Island, Stonehenge, and the Cowboy Bar in Meeteetse, Wyoming. Some breathtaking observations have been made there this autumn — truly breathtaking, I tell you.

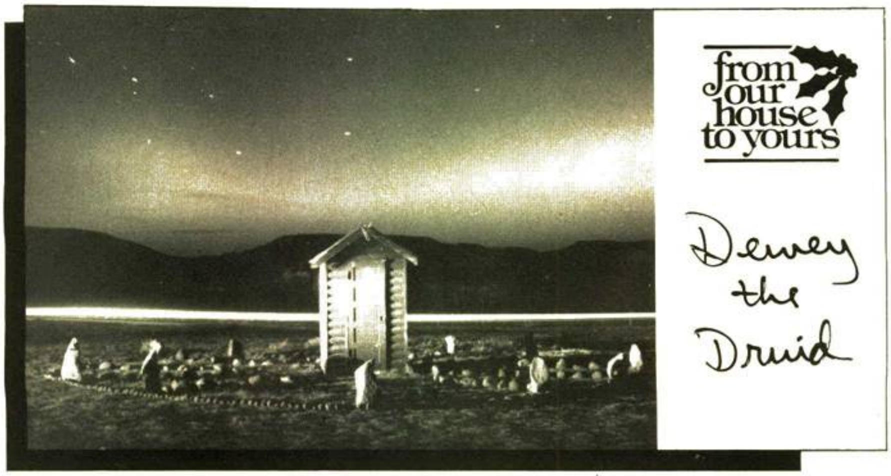
We received a government grant (from the government of Latvia) to upgrade the lighting system in the main telescope housing. Thanks to that unsolicited display of human generosity, we no longer have to burn sheep fat and beef tallow for illumination. You will notice that the new lighting adds a real warmth and ambience to the Observatory.

The sheephead over the Observatory door is an unfortunate necessity, part of our security system. It keeps undesirables away during daylight hours when the astronomers take their sleep. We hope to get another grant in 1985 to help eradicate the flies.

Well, that's the report from Wyoming for this year. We're busy packing for our Annual Decadent Astronomers' Ice Fishing Regatta, this year's trek being for large-mouth bass on the nucleus of Halley's Comet. They're hitting worms, we hear. And as long as we're so close to Jupiter, we may wet a line or two for baby squid on Europa.

That's all for now . . . CHEERS!

Dewey Vanderhoff
Mack Frost
Ed Leikam
Cody, Wyoming



Searching for Comet/Asteroids

Sir / Regarding the article "Can Comets Become Asteroids?" by John Davies, ASTRONOMY, January 1985: Willy Ley, in his *Watchers of the Skies*, wrote that astronomer J. Comas Sola of Barcelona "repeatedly photographed the asteroids 182 Elsa, 224 Oceana, and 899 Jocaste with halos, as if they had atmospheres."

Are these three "transition comets"? If they are, they'd be extremely useful for future manned missions to the asteroid belt. The volatiles could supply some of the water, oxygen, and fuel for the mission.

Unfortunately, the three are difficult to observe. When closest to Earth, Elsa is in the magnitude 11 to 14 range, Oceana can reach 13, and Jocaste varies from 14 to 16 at opposition.

If any readers of ASTRONOMY would be interested in forming a patrol to monitor these three objects during closest approach, I would like to hear from them. We need amateurs with astrophotographic capabilities. I can generate ephemerides for them.

Harald Schenk
2330 S. 11th St.
Sheboygan, WI 53081

Sirius B in a 6-incher

Sir / I'm not sure I agree with John D. Lawyer (In Focus, December 1984) that Sirius B is difficult to see in telescopes of 6 to 8-inch aperture.

After all, the magnitude of the Pup is 8.6 and the distance between primary and secondary is a full 8" at present.

Up until December 2nd last year when I first tried to see Sirius B, I had thought much the same as others about the difficulty of the task. So I was most surprised to find how easy the Pup was! On the night in question the seeing was so-so: at times Sirius would just spread out over the companion. But at other times, the Pup was bright and clear — just as you'd expect from such a bright little star with such a separation from the primary.

My telescope? A 6-inch f/8 reflector at 135x.

Gwyneth Hueter
Lostock, Bolton, England

Free Newsletter for Teachers

Sir / An astronomy newsletter for teachers and librarians of grades 3 through 12 is available without charge from the Astronomical Society of the Pacific and the American Astronomical Society. The newsletter includes short, nontechnical articles on new developments in our exploration of the universe; practical classroom activities for teaching astronomy; and suggestions for written and audio-visual resources on astronomical topics.

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Andrew Fraknoi
Executive Officer
Astronomical Society of the Pacific
San Francisco, CA

Quasars and Redshifts

Dear Sir / Jack Sulentic's article "Are Quasars Far Away?", which appeared in the October issue, was outstanding. I accept the premise that quasars are incredible powerhouses, but in my opinion their nature introduces problems when interpreting redshifts. Hubble's Law remains true at the apex of distance measurement, but doesn't seem to hold true for quasars. This doesn't mean that Hubble's Law is wrong or stands to be banished as "one of the old theories," but I think it no longer applies for quasars.

We're faced with a paradox: How can an object be 1000 megaparsecs farther away than a galaxy with which it interacts? The great example, NGC-4319 and Markarian 205, can't be ignored. It seems the first step is accepting that there is a problem in measuring distances to quasars, then we can work on correcting it. Before the dawn of most great discoveries, great disagreement exists on whether or not to proceed.

Don Garrod
Indianapolis, IN

More Local Group Members?

Dear Sir / I was surprised and pleased to see David J. Eicher's excellent article on observing the Local Group of Galaxies in the November ASTRONOMY. Your listing was exhaustive and provided a great deal of information to digest. However, I've seen listings in some technical books of other galaxies that are supposedly members of the Local Group — NGC 6946 in Cygnus, Maffei 2, four dwarf satellites of the Andromeda Galaxy, and NGC-1569 in Ursa Major. Are these galaxies visible in amateur telescopes and if so, why weren't they included?

John H. Hanson
Westerly, RI

Mr. Hanson: Judging by published magnitudes and surface brightnesses, the article included everything in the Local Group that is visible with a "standard" backyard telescope. The four dwarf galaxies orbiting around M-31 and Maffei·2 are impossibly faint, while current distance estimates on NGC-6946 and NGC-1569 place them outside of the Local Group of galaxies.

Behind the Scenes

Our New Star Dome Map

The beginnings of our new Star Dome map date back five years — to the day we finished our former Star Dome map. After plotting about 5,000 of that last map's 6,000 stars, I said to myself, "There's gotta be a better way!" Well, to make a long story short: computers now plot all of ASTRONOMY's star maps.

As you've probably noticed, ASTRONOMY uses quite a few star charts. In addition to Star Dome, we prepare a constellation map for the Backyard Astronomer every month. We often feature special maps to help you in your observing: February's Comet Halley map, last year's Pluto map, and the maps that accompanied Earle Dodds' six-part series on the constellations.

For our new Star Dome, we looked into a variety of cartographic projections — finally settling on the classic stereographic chart of the sky. This projection renders all the constellations in their true shapes without distortion, and nicely mimics the apparent sizes of constellations both near the horizon and high overhead. After we humans spent months compiling an accurate data base of each and every star to be plotted, the computer whipped through the spherical trigonometry in about 20 minutes!

But there's a lot more to a good star map than just stars. With the basic design in hand, we asked world-famous Dutch celestial cartographer Wil Tirion (of *Sky Atlas 2000.0* fame) to "decorate" our raw computer plots with all the touches that make a star chart look and feel right — star and constellation names, Greek letters, deep-sky objects, and, last but not least, a graceful outline of the Milky Way.

We took charge again at the production end, using the computer to help us color each of the stars according to its temperature. We also picked tints that make the charts look good in daylight — yet remain readable under the ruddy glow of a flashlight outdoors at night. All of us who have had a hand in preparing them hope you will find our new charts both informative and useful. Happy stargazing!

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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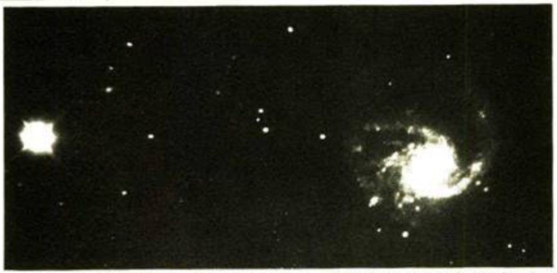
LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH



Spiral Galaxy NGC4254 (M-99) in Coma Berenices. The spiral arms of this lovely 10th magnitude galaxy can be seen in larger aperture telescopes. Photo by Dr. Jack Marling using a LUMICON EASY-GUIDER and 2415 film sensitized in a LUMICON Model 300 HYPER-KIT. 40 minute exposure, 24"f/6.5 telescope.

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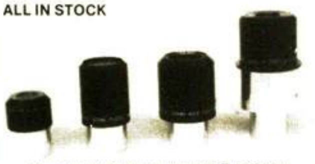

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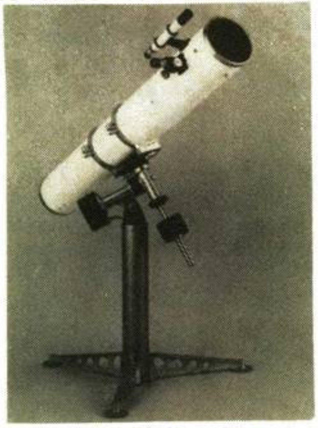

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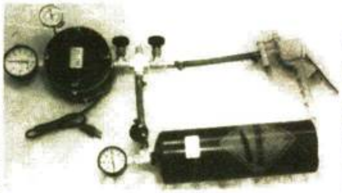

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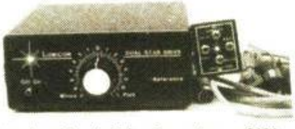

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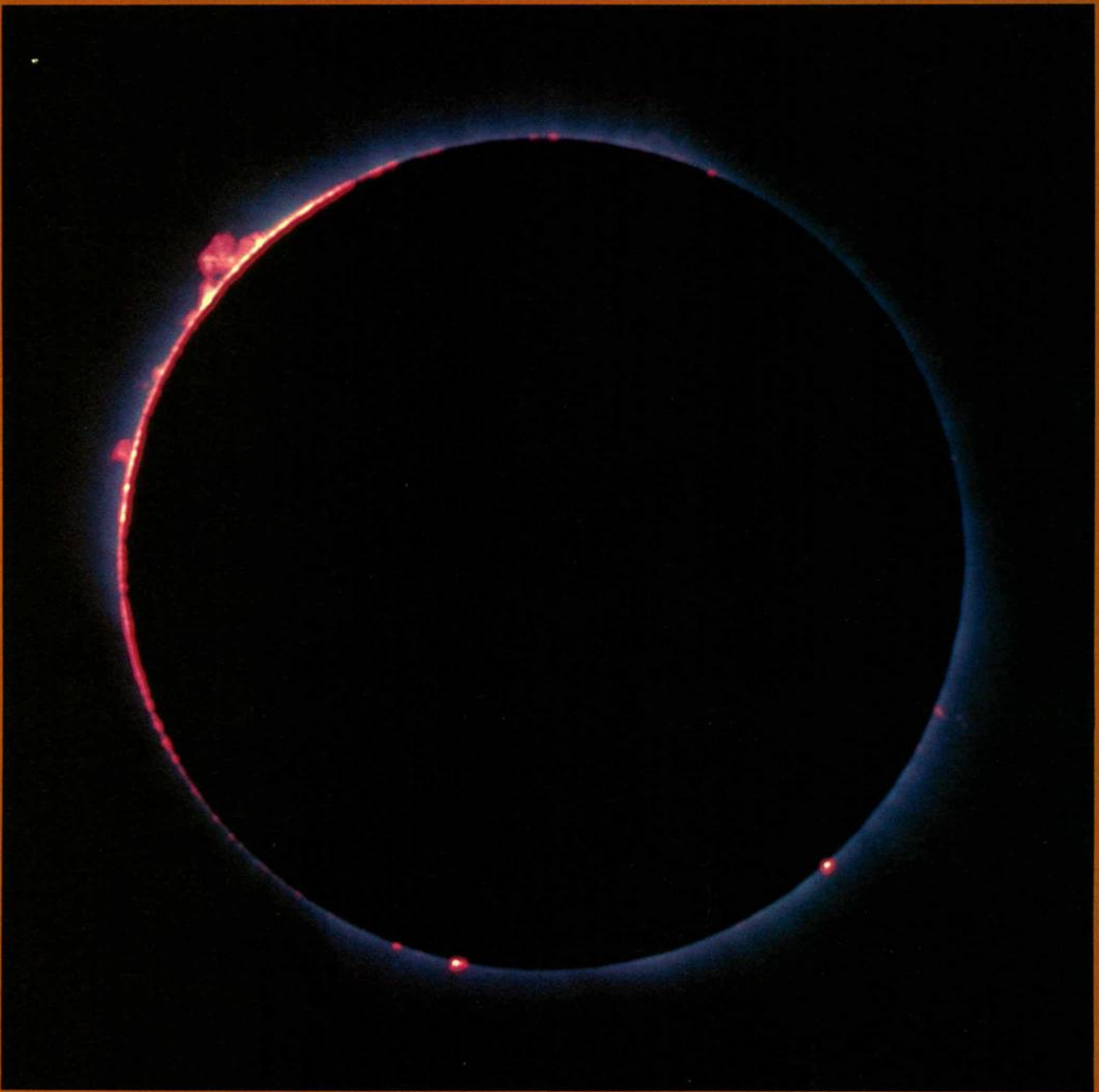
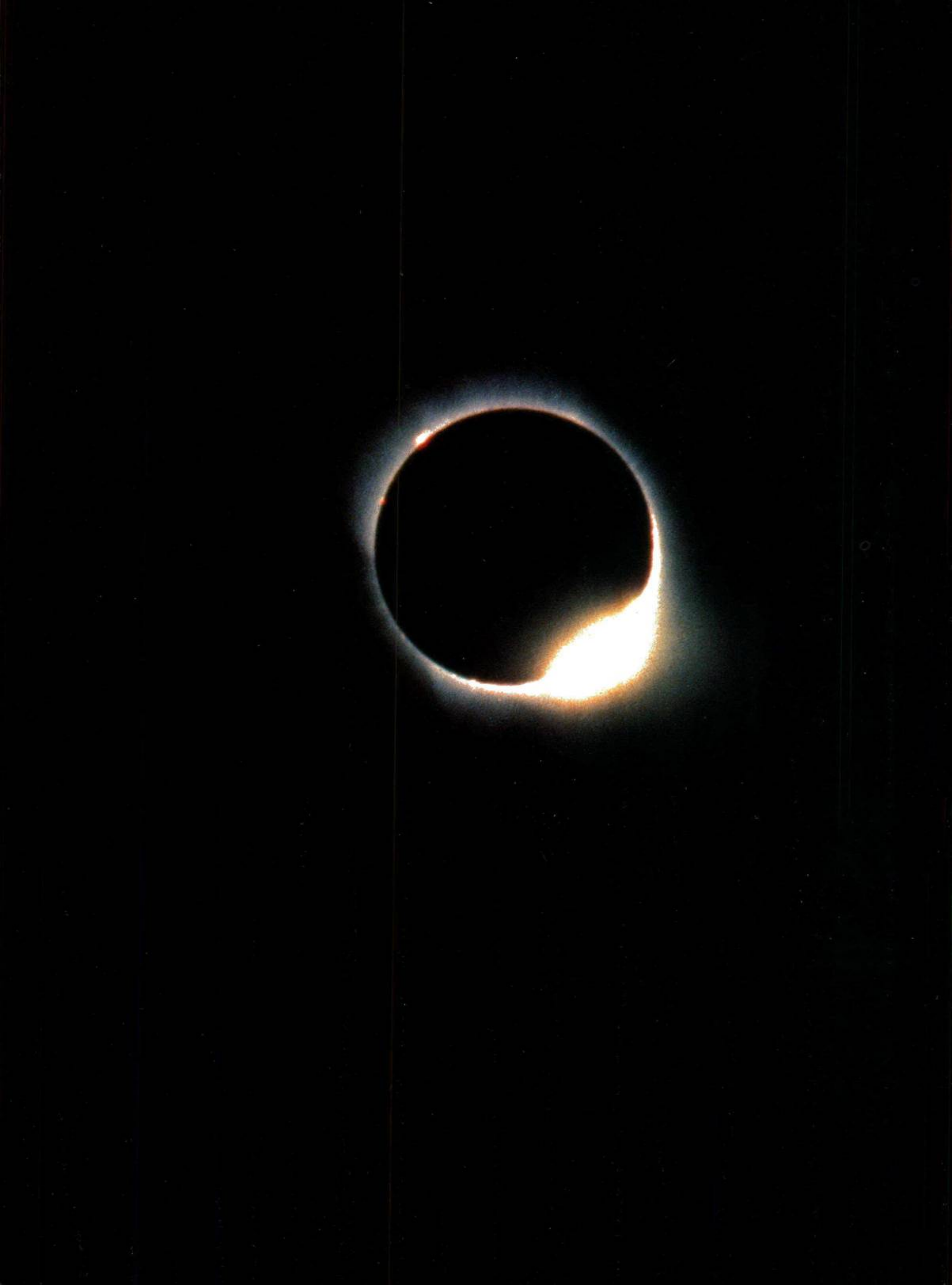
D-19 B&W Developer	1 gal.	**$6.95**

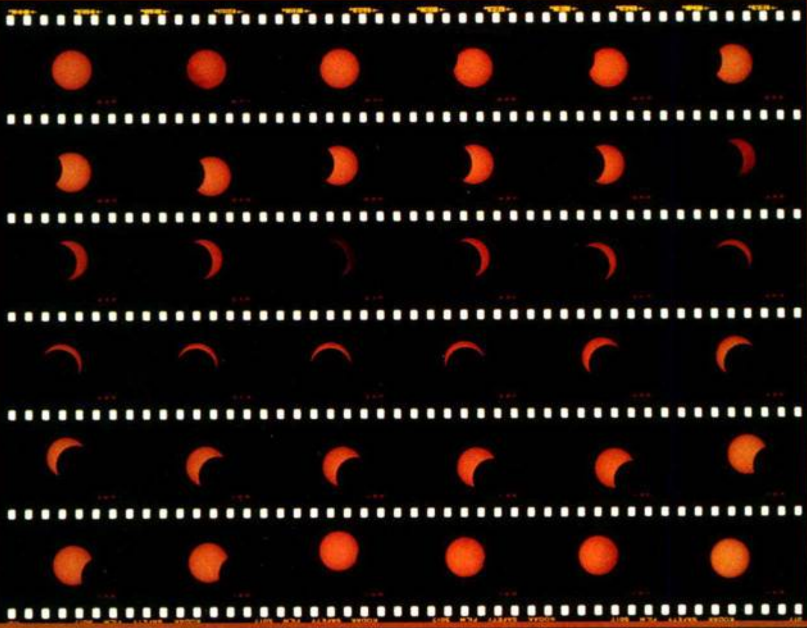
Eclipse over Oceania

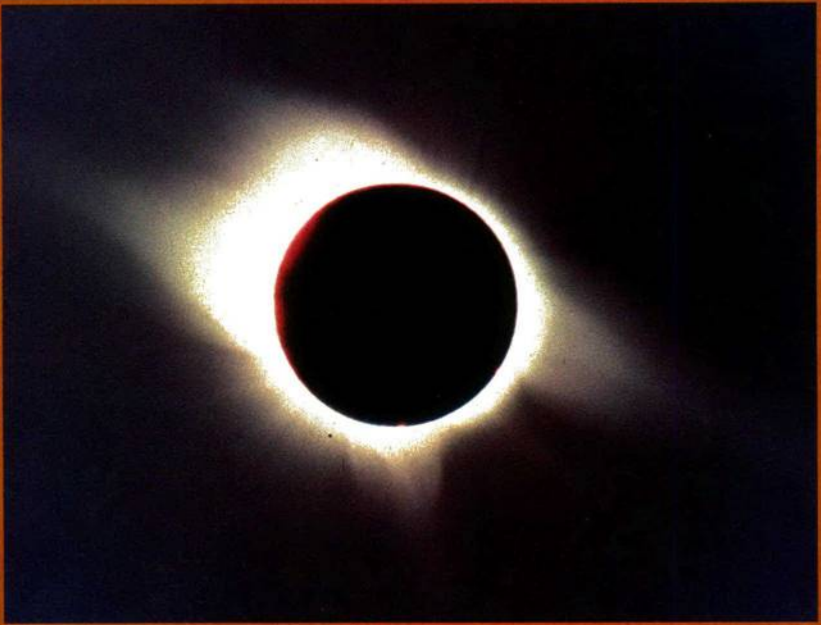
Just before third contact at his observing site in Hula, Papua New Guinea, Jacques Guertin caught this view of the November 23, 1984 total solar eclipse. When the battery pack for his telescope's clock-drive failed, he had to track manually and keep his exposures to ⅛ second. Guertin was equipped with a 6-inch f/19 Maksutov and Kodak 2483 film (a color emulsion for photomicrography).



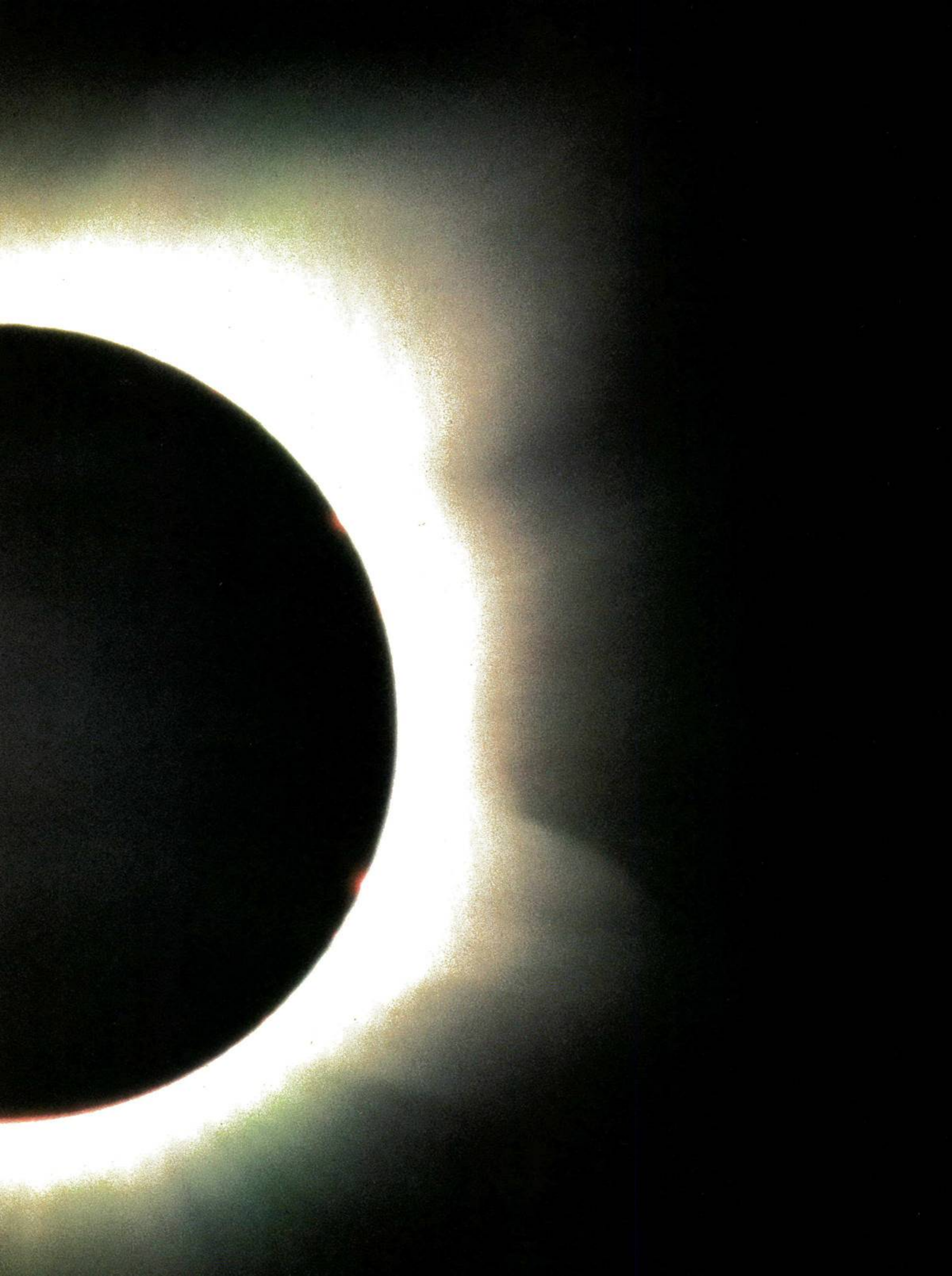


Left: Jim Manning saw the eclipse from aboard ship in the Coral Sea off Noumea, New Caledonia. His photo shows the "diamond ring," which was visible just before second contact. He used a 400mm lens and $\frac{1}{1000}$-second exposure on Ektachrome 400 film. Below: Working from his home in Auckland, New Zealand, Luciano Nustrini compiled a photo sequence showing the partial eclipse (beginning at upper left). Nustrini used a 4-inch f/12 refractor with a full-aperture solar filter and $\frac{1}{500}$-second exposures on Ektachrome 64 film.





Above: Ernest Piini was in Hula, PNG; he used an occulting disk in front of the camera's focal plane to reduce the inner corona's brightness and let it record along with the faint outer streamers. The half-second exposure was taken at f/7 on Ektachrome 200. Overleaf right: Randy Attwood, also at Hula, recorded this view displaying the spiky coronal streamers at the Sun's north and south poles. His equipment was a 3½-inch Maksutov and the exposure was half a second at f/16 on Ektachrome 200 film.



ASTRONOMY Reviews

2010

Written and directed by Peter Hyams
Based on the novel by Arthur C. Clarke
Metro-Goldwyn-Mayer (1983)

The motion picture *2010* is a "Star Warred" and "Star Trekked" version of the classic science fiction film *2001: A Space Odyssey* — and the result is disappointing. Perhaps it's a sign of the times, but the new sequel to the 15-year-old *2001* lacks the cerebral appeal of the earlier movie.

For anyone familiar with lunar geography, the spell is broken during the film's first minutes. In a short recap of the original movie, it makes reference to the Tycho Anomaly in the Sea of Tranquility. However, the Tycho Magnetic Anomaly discovered in the first movie was nowhere near the Sea of Tranquility. It was, of course, inside the crater Tycho in the Moon's southern highlands. You can call that quibbling over a technicality, but it sets the tone for the rest of the movie.

The first dialogue occurs at an appropriate setting — the Very Large Array radio telescope in New Mexico. There, Dr. Heywood Floyd, an American official who has somehow been saddled with the apparent "failure" of the *Discovery*'s mission to Jupiter nine years earlier, is confronted by a Russian official who seems to appear out of thin air. Although the United States and the Soviet Union are approaching war with each other — we are constantly reminded of this throughout the movie — a high-ranking Soviet official has somehow found it easy to openly flit about a major American scientific facility unannounced.

Both countries are planning flights to the jovian system to find out what happened on the ill-fated *Discovery* mission, and the Russian spacecraft will be ready first. The latest computations show that *Discovery*'s orbit is rapidly deteriorating and the old ship will crash long before the American mission can reach it. Lacking the necessary expertise, the Russians don't believe they'll have enough time to unscramble HAL — the super-smart, but somewhat paranoid computer that went haywire on the original mission. They need American know-how and invite their participation on the flight.

The Americans agree to go and experience various misadventures during the rest of the movie, until mysteriously directed to leave the area of Jupiter because "something wonderful" is going to happen. One of the best scenes — one that returns us to the original movie in many ways — occurs when David Bowman, the last of the long-lost *Discovery* astronauts, appears with that message for Dr. Floyd.

Unfortunately, *2010* is filled with the familiar defects found in most space movies. For example, we are treated to enormous roars from rocket engines and streaking fireballs — all in the soundless vacuum of space. Astronauts and cosmonauts alike show incredible amounts of sweat-filled terror during any moment of stress. It's hard to believe that a civilization active in space travel for half a century would send these white-knuckled nervous wrecks on such an important mission.

Amid its formidable message about how meaningless patriotism and world politics are away from Earth, the film makes other statements — some of which may have been unplanned. For example, none of the Americans know a lick of Russian, but the cosmonauts, given an occasional slip during an attempt at humor, are fluent in conversational English.

If you think the *Star Wars* genre of films is the greatest ever, then no doubt you'll enjoy *2010*. But if you're looking for something deeper, don't get your hopes up. Perhaps the original *2001* set too high a standard to be matched by a sequel. But *2010* only occasionally comes close to making the grade — and fails elsewhere with a nondescript soundtrack and a slavish devotion to current special effects. You end up leaving the theater with the uneasy feeling that space technology somehow went backward in nine years.

The Hollywood types who promote *2010* say you needn't see the original to enjoy its sequel. They better hope you didn't. *Ray Grasshoff.*

Wonders of the Sky

Fred Schaaf
299 pages, paperback, $6.95
Dover (1983)

Occasionally an astronomy book appears which has an elusive, hard-to-define quality that gives it broad appeal to a diverse audience. Martha Martin's *The Friendly Stars* has it, and so do W. T. Olcott's *Field Book of the Skies* and R.H. Allen's *Star Names*.

Books such as these tend to stay in print for a long time and become near classics, which are perennially discovered by fresh groups of readers. Easy-to-read, knowledgeably written, and often appealing to readers' esthetic sensibilities, books like these initially capture one's interest and then are turned to again and again for reference.

I predict that Fred Schaaf's *Wonders of the Sky* will turn out to be such a book. While not specifically an observing manual or a textbook, it has characteristics of both. Schaaf has an obvious appreciation for natural phenomena and in a clear conversational style, he conveys a contagious enthusiasm for the naked-eye delights of Earth and sky.

Divided into three sections, the volume follows an outward-bound, Earth-to-stars format. The first section describes visual phenomena in the atmosphere, the second describes and explains solar system objects and events, and the third introduces readers to the stars.

Schaaf begins with what many consider the most striking and colorful terrestrial display — the multi-hued rainbow. He describes the structure and dynamics of rainbows and explains their delicate traceries of color, then moves on to moonbows, fogbows, halos, coronas, glories, and related atmospheric phenomena.

From the bottom of the atmosphere, Schaaf takes his reader upward to the realm of parhelia and kindred phenomena, into the lacy cirrus clouds of miniature ice prisms. Moving still higher, he explains why the sky is blue and describes the use of a cyanometer with which to measure and contrast the nearly infinite hues of the sky. Next come the rarefied regions where meteors first begin to glow as they race into the Earth's tenuous upper atmosphere.

The second section of the book investigates eclipses, comets, and the planets. Schaaf, founder of the quarterly publication *Dark Skies for Comet Halley* and a staunch advocate for dimming unnecessary artificial lighting, writes eloquently about some of the solar system's transient events. For example, describing a comet's passage through our planet's neighborhood, he says "a vast feather of radiance hangs above the first awakening white gold of morning twilight. Small stars still twinkle all around and even through the ends of the glowing, diaphanous veil high in the sky, while down below, the big fiery star from which the plume of light extends burns in the brightening dawnlight with intense, enduring radiance."

The last portion of the book deals with the infinite vastness of the heavens. It has simple but usable star charts, and for added flavor a good measure of mythology and star lore is included.

The book concludes with eight concise but informative appendices which list the brightest stars, naked-eye conjunctions of planets and stars through 1993, and a list of naked-eye objects.

Flip through the pages and you find line drawings and black and white photographs. Here and there are tables and diagrams. The front and back inside covers are decorated with a dozen color photos. The book is well-bound in the usual Dover manner.

Overall, it is a practical, detailed, and informative commentary on the heavens. But most of all, it is a volume written with care and a sense of delight in the visual pleasure around and above us. *Wonders of the Sky* is a gentle, perceptive book. *Gail O. Clark.*

Report of the Optical Conference on the 7.6-Meter Telescope
Harlan J. Smith and
Thomas G. Barnes III, eds.
456 pages, softcover, no price given
Univ. of Texas Astronomy Dept. (1984)

This transcript of a meeting held in Austin, Texas, from March 22 to 24, 1982 discusses the feasibility of building a 7.6-meter telescope in Texas. Illustrated with several diagrams, the volume is primarily dialogue between scientists such as Roger Angel, Fred Gillett, Aden Meinel, Gerry Neugebauer, and J. Craig Wheeler.

Rainbows, Snowflakes, and Quarks
Hans C. von Baeyer
192 pages, hardcover, $16.95
McGraw-Hill (1984)

Billed as a physics book for non-physicists, the book explains the "how" of many everyday phenomena. Besides those mentioned in the title, it also covers such topics as gravity, lightning, waves, sky colors, and how a compass works.

Quantum Gravity
M.A. Markov and P.C. West, eds.
548 pages, hardcover, $79.50
Plenum Press (1984)

This work, intended for professional physicists, records the proceedings of the Second Seminar on Quantum Gravity, held in Moscow in October 1981.

Exploring the Moon Through Binoculars and Small Telescopes
Ernest H. Cherrington, Jr.
229 pages, paperback, $10.95
Dover Publications (1984)

This work first appeared in 1969, and provided a guide and handbook to the lunar surface as seen in small instruments. The "maps" — showing the Moon at one day intervals throughout the lunar cycle — are photos of the Moon's entire disk annotated with place-names. Each is accompanied by a full description of the topographic features visible on that day. In addition, there are several close-up views made at high power. Chapters also describe the equipment for observing and some basic facts about the Moon. New for this edition is a special preface indicating where the text is out-of-date, and a section of 16 photos taken by spacecraft (the majority Lunar Orbiter views).

Planetary Rings
R. Greenberg, A. Brahic, eds.
784 pages, hardcover, $35
University of Arizona Press (1984)

Three planets are known to have ring systems — Saturn, Jupiter, and Uranus. This work gathers technical papers by 44 authors that cover all aspects of ring systems. It is published as part of the University of Arizona's Space Science series.

The New Atlas of the Universe
Patrick Moore
271 pages, hardcover, $40.00
Crown (1984)

This work is an updated and expanded version of Patrick Moore's 1978 *New Concise Atlas of the Universe*. The large-format, tabletop book contains sections on stars and planets, along with a star atlas.

Saturn
T. Gehrels, M.S. Matthews, eds.
968 pages, hardcover, $37.50
University of Arizona Press (1984)

Published as part of the Space Science Series, this volume on Saturn summarizes the professional knowledge about that planet as of late 1983. Most of the material is highly technical; but as with the other works in this series, the book contains several review articles including "The Saturn System," "Saturn Through the Telescope," and "Satellites of Saturn: Geological Persective" that are comprehensible to any interested lay person.

Astrophysics Today
A.G.W. Cameron, ed.
337 pages, paperback, $19.95
American Institute of Physics (1984)

An anthology of nearly 60 articles from the AIP's magazine *Physics Today*, this work covers such topics as the interior of the Moon, the history of the American Astronomical Society, ultraviolet astronomy, the Multi-Mirror Telescope, the evolution of red giant stars, black holes, SS 433, Hercules X-1, quarks, quasars, and why the night sky is dark — to name only a few. The level of presentation is equivalent to *Scientific American*.

The Invisible Universe
George B. Field and Eric J. Chaisson
195 pages, hardcover, $19.95
Birkhaeuser (1984)

Both Field and Chaisson are research astrophysicists heavily involved in studies of "the invisible universe" — astronomy carried out at non-optical wavelengths. Written for lay readers, this book is intended as a report on the frontiers of astrophysics. It has eight chapters, including "Radiation, Visible and Invisible," "Planets, Life, and Intelligence," "Cosmic Violence," and so on — each prefaced with a personal anecdote by Field or Chaisson that points up some aspect of research they have been involved with.

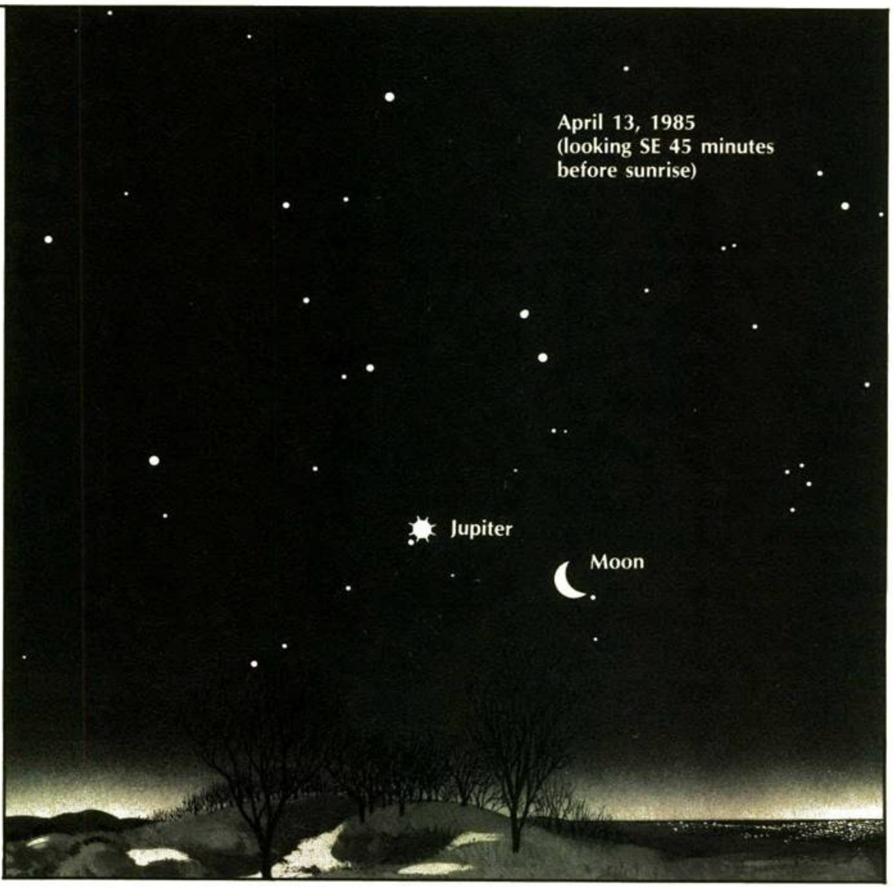
Space and Society
P. Anaejionu, N.C. Goldman,
P.J. Meeks, eds.
429 pages, paperback, no price given
American Astronautical Society (1984)

In 36 papers originally presented at a conference in April 1982, 27 authors explore the role of space exploration in various societies around the world. The topics range from "Economic Issues of Colonizing Space" and "Japanese Space Industrialization" to "Lunar and Asteroid Mining" — to name a few.

Saturn Shines in the Evening

by

Fred Schaaf


April 13, 1985
(looking SE 45 minutes before sunrise)
Jupiter
Moon

The Wanderers

April brings a variety of sights: Saturn rises earlier and brightens, Venus passes from the evening to morning sky, and Jupiter "adds" a stellar member to its moon system.

Golden **Saturn** continues brightening as it approaches opposition in mid-May. Beginning skywatchers may be surprised that this planet isn't even brighter, but most people who see Saturn now will find it fairly impressive, since for the first time in many years, Saturn will shine at nearly zero magnitude as it comes to opposition.

By the end of April, Saturn's brightness will be magnitude +0.2, similar to Arcturus when it is up high. Saturn is slowly retrograding toward two faint naked-eye stars; it will pass near them next month. Try glimpsing fourth-magnitude Gamma (γ) Librae, about 4° northwest of Saturn. This month, Saturn and Jupiter are an equal distance south of the celestial equator at about −17.3° declination. At around the same time, Mars is almost 17.3° north of the celestial equator. Whereas Jupiter is moving farther north, Saturn continues creeping south toward the splendid stars of Scorpius with which it makes a fine display after midnight on April nights.

Since **Jupiter** is approaching western quadrature (90° west of the Sun), it is best visible before dawn when moderately high in the southeast. A dazzling magnitude −2 object, Jupiter gets some company from Venus when it enters the morning sky this month. Jupiter continues its slow eastward course and at the month's beginning lies within a Moon's diameter of sixth-magnitude 19 Capricorni. Creeping along just south of the ecliptic, it passes only four arc-minutes north of 4.2 magnitude Theta (θ) Capricorni around 22h UT on the 18th. This star is brighter than any of Jupiter's satellites and should make a beautiful "addition" to the Galilean system for several nights. The best views will come with binoculars or a telescope, but see how close to Jupiter you can detect Theta with your unaided eye.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Although it has a few similar conjunctions in the next two years, Jupiter does not come this close to any bright star during its next 12 year cycle. The next best event will be on the American morning of September 10, 1991, when little more than one-third of a degree will contain Jupiter, Regulus, and Mercury.

Two planets near the Sun are Mars and Mercury. By month's end, **Mars** reaches a 23° elongation from the Sun but merely shines at second-magnitude. It then speeds several degrees south of the Pleiades, making observation impossible.

Mercury zooms through inferior conjunction on the 3rd, is closest to Earth on the 27th, and farthest from the Sun in space (aphelion) on the 24th. Presenting a fine evening showing for the northern hemisphere during March, this little planet now hangs low on the eastern horizon in the dawn sky. On May 1, Mercury will be at greatest elongation — almost 27° from the Sun — but will still be difficult to see, located only about 4° above the horizon.

The crescent Moon sets in the western sky, passing over a series of television transmission towers. Photo by Frank Zullo; 200mm f/4 lens, 400 ISO film, 3-second exposure.

Venus fades to magnitude −3.2 and twinkles as a one arc-minute long skinny crescent as viewed in binoculars. Naked-eye viewers might see it a few degrees above the horizon 10 minutes after sunset. Can you observe Venus both before dawn *and* after sunset on April 1st?

Venus will be closest to Earth at 17h UT on the 3rd, when it is 0.2826 astronomical unit (AU) or 26.2 million miles away, showing a crescent 59.5 arc-seconds across. Later during April, Venus' altitude increases from 5° to about 15° above the eastern horizon at sunrise. Meanwhile, it rises a full magnitude in brightness. By April 30, the planet's elongation is 30° and greatest brilliancy occurs nine days later. Venus resumes direct motion on April 25 and will not retrograde again until its next inferior conjunction in October 1986.

The Starry Sky

If we look above the western horizon shortly after sunset, we see Sirius, Orion, Aldebaran, the Pleiades, and Perseus. Once darkness falls, you can see the Milky *Way, Capella, the twin stars Castor* and Pollux, and Procyon. The constellations containing these last four stars are **Auriga** the Charioteer (Capella), **Gemini** the

April's Night Sky

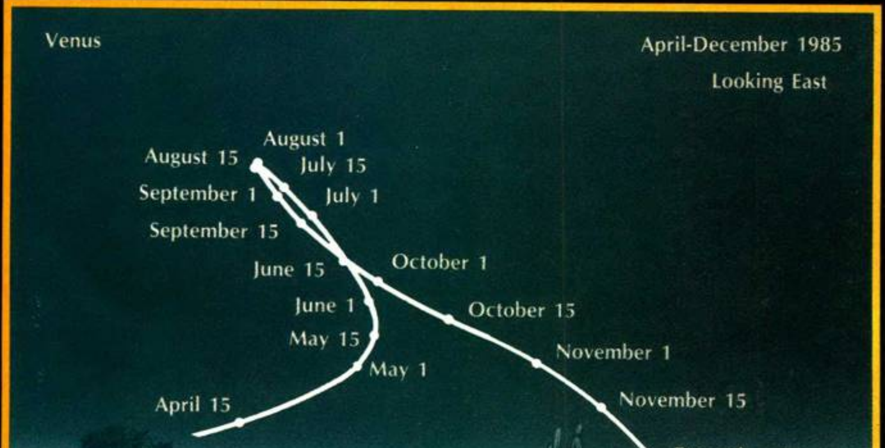
Full Moon
April 5
6:32 a.m. EST

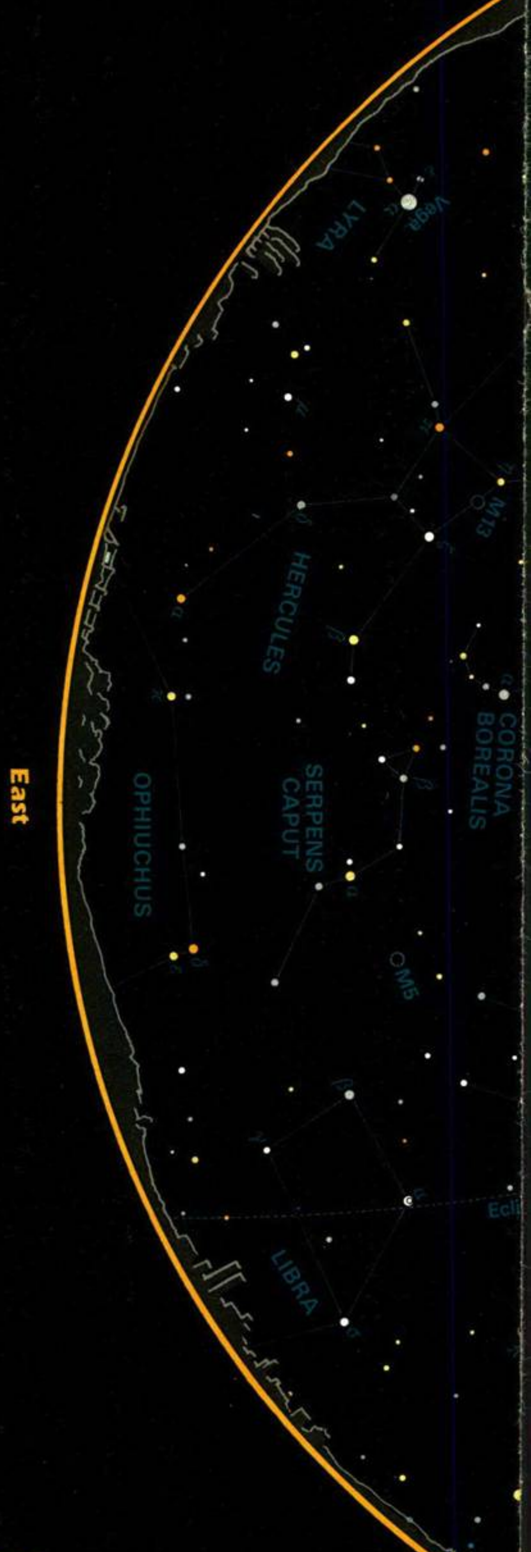
Last Quarter
April 11
11:41 p.m. EST

New Moon
April 20
12:22 a.m. EST

First Quarter
April 27
11:25 p.m. EST

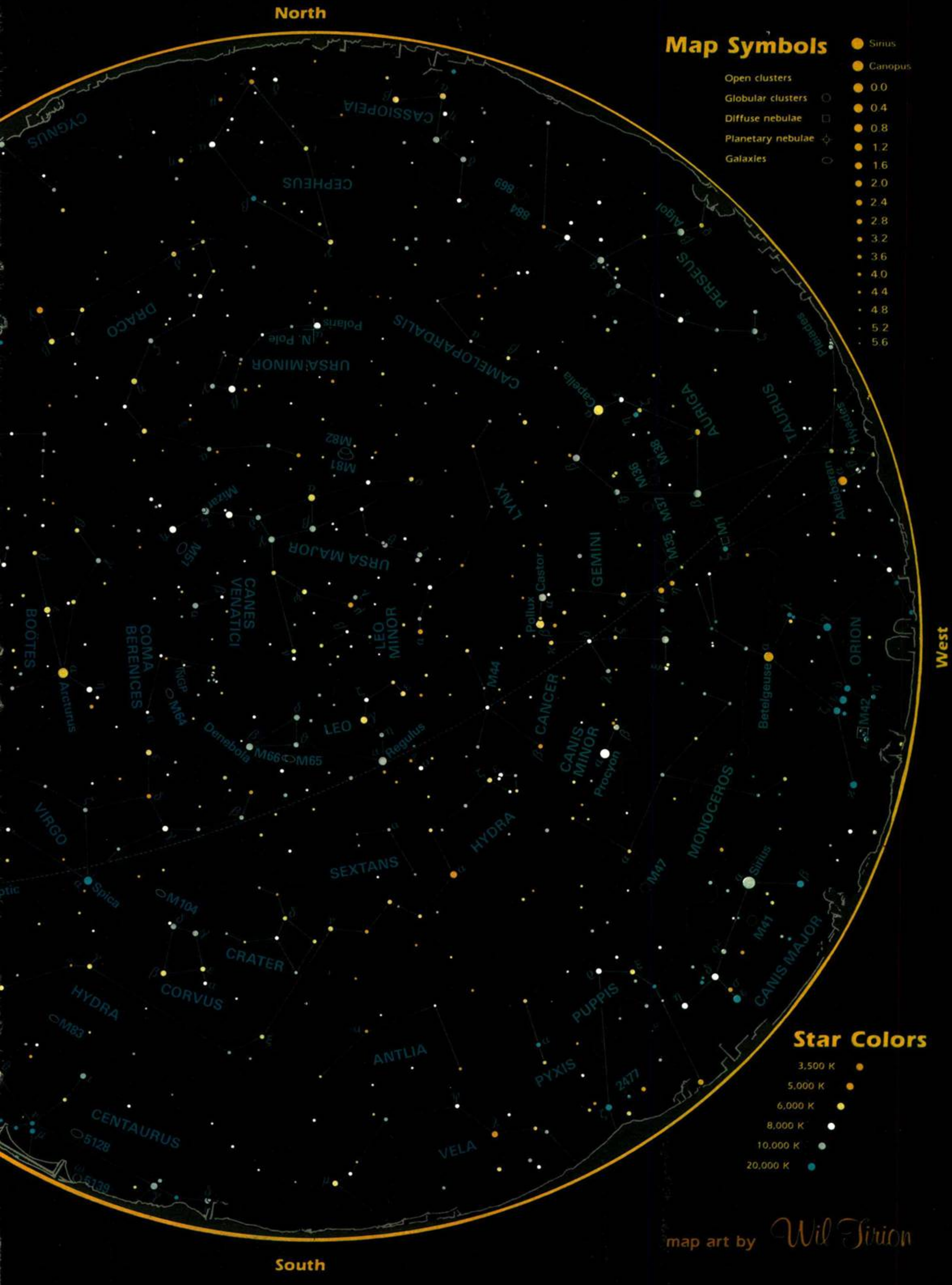
3rd	Mercury and Venus both pass through inferior conjunction, shifting from the evening to the morning sky. How soon can you spot them?
5th	The Moon is Full at 6:32 a.m. EST, and closest to Earth at 1:28 p.m. EST: 221,813 miles.
11th	Last Quarter Moon occurs at 11:41 p.m. EST.
13th	Today and tomorrow the Moon passes south of Jupiter in the pre-dawn sky.
15th	Around 11:30 p.m. local time — just about as Spica in Virgo crosses the meridian — the Milky Way will circle the horizon. You are then looking up and out at the northern galactic hemisphere.
19th	The Moon is farthest from Earth at 12:23 p.m. EST: 252,612 miles.
20th	New Moon occurs at 12:22 a.m. EST.
22nd	Mars lies close to the Moon in the evening sky.
21st	The April Lyrid meteor shower reaches peak activity; best views will be after midnight. These meteors are bright, and observers away from city lights should see about 10 to 20 per hour coming from the region between Vega and Hercules.
27th	First Quarter Moon is at 11:25 p.m. EST.
28th	Daylight Saving Time begins — 2:00 a.m. local time becomes 3:00 a.m.





The Star Dome shows how the sky looks at:

9:30 p.m. on April 1st
8:30 p.m. on April 15th
7:30 p.m. on April 30th


North
Map Symbols
Sirius
Canopus
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
CYGNUS
CASSIOPEIA
CEPHEUS
869
884
Algol
PERSEUS
Pleiades
DRACO
Polaris
N. Pole
URSA MINOR
CAMELOPARDALIS
Capella
AURIGA
TAURUS
Hyades
Aldebaran
M82
M81
LYNX
M36
M38
M37
M35
M1
Mizar
M51
URSA MAJOR
CANES VENATICI
GEMINI
Castor
Pollux
LEO MINOR
BOÖTES
COMA BERENICES
NGP
M64
Arcturus
LEO
Denebola
M66
M65
Regulus
M44
CANCER
CANIS MINOR
Procyon
ORION
Betelgeuse
M42
MONOCEROS
VIRGO
HYDRA
SEXTANS
M47
Sirius
M41
CANIS MAJOR
Spica
M104
CRATER
CORVUS
HYDRA
M83
ANTLIA
PUPPIS
PYXIS
2477
CENTAURUS
5128
5139
VELA
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
West
South

map art by Wil Tirion

Top: The springtime stars Castor and Pollux (above center), Procyon (left center), and brilliant Venus set over the Grand Teton range in Wyoming. Photo by Dewey Vanderhoff; 28mm f/3.5 lens, 400 ASA, 52-second exposure. Bottom: Venus, Jupiter, and the Moon hang high over Chicago's western sky. Photo by Peggy Stevens; 55mm lens, no exposure data available.

Twins (Pollux and Castor), and **Canis Minor** the Little Dog (Procyon). They are winter lingerers, but — like a late frost — you can still enjoy their sparkle before they set for the season.

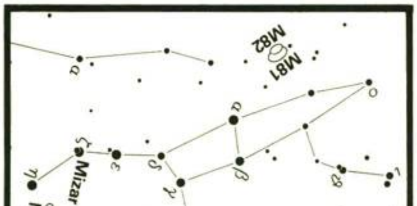
In August, these constellations will again emerge before dawn — the same time many spectators will be searching for **Comet Halley** in northeastern Orion. One year from now, this legendary comet will be at its closest approach to Earth and will probably display its longest tail.

Turning eastward, we see **Arcturus** and **Spica**. The Full Moon will pass between them on the 15th. Across most of the sky, however, the constellations are not terribly bright except for two along the meridian at mid-evening — Ursa Major the Great Bear and Leo the Lion.

Ursa Major is a large constellation containing the most famous asterism in the sky, the Big Dipper. Most people in North America and Europe now see the Bear and Big Dipper hung upside-down, high in the northern sky. As far north as Great Britain, where the Dipper is known as the Plough, the constellation actually passes through the zenith.

As all skygazers should know, following the *arc* of the Great Bear's tail (or Big Dipper's handle) brings us to *Arc*turus meaning "bear-guard" — one who guards the constellations from the fearsome Bear. A line from the Bear through Arcturus leads to Spica, the second brightest of spring's stars.

Best known, however, is the technique of using the Big Dipper — Dubhe and Merak on the western side of the bowl — to guide us to Polaris, the North Star. In the middle of an April evening, this line points straight toward the horizon. Note that the Big Dipper's bowl is tilted slightly when at its highest.



Leo the Lion features Regulus, one of only three first-magnitude stars in the springtime sky. The stars which we can easily imagine as the curve of the Lion's shaggy head are called the Sickle. Regulus is the base of the Sickle's handle, but a famous telescopic double star in the Sickle's curve is also visible. This star, Gamma (γ) Leonis, is called Algeiba.

Despite the prominence of the Sickle, the rest of Leo is a bit tricky for the beginner to find. It is almost due east of the Sickle, but roughly a full hour of right ascension behind with little for the naked eye. The posterior stars form a prominent right triangle and contain bright second-magnitude Denebola.

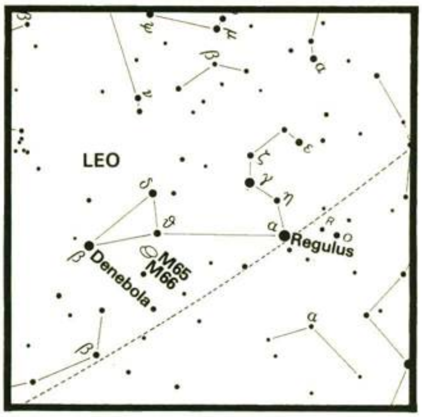
From Regulus, venture northwest toward Pollux and you'll find **Cancer** the Crab, which contains beautiful M-44 — the Beehive Cluster. The Beehive is more traditionally called Praesepe, the "manger" at which the Northern and Southern Asses feed. These asses are Gamma and Delta (δ) Cancri (Asellus Boreallis and Asellus Australis), each rather faint stars just northeast and southeast of M-44. Just south of Cancer is the prominent head of Hydra the Sea Serpent, and southeast of the head is Alphard — the monster's heart. This second-magnitude orange star is brightest in a large section of sky, earning its name meaning "the solitary one."

Tucked between Hydra and Leo is dim **Sextans** the Sextant, and between the Great Bear and the Lion is **Leo Minor** (the Little Lion). Other smaller constellations and asterisms can be found in the spring sky. We will pursue them and some of spring's more obvious stellar riches next month.

Skylore

Leo the Lion has a firm place in legend through the names of his stars. One of the most famous of Leo's stars is Regulus (Alpha Leonis), the diminutive of the Latin rex, meaning "king." The name dates back 5,000 years to the Sumerians in Mesopotamia. The name "Regulus" may have been popularized by Copernicus, although it was used centuries before him. From the Arabic Dhanab al-Asad, Denebola (Beta Leonis) is known as "the tail of the lion." Though the Coma Berenices star cluster once marked the tuft of the Lion's tail, modern representations show the tail's end marked by Denebola. Together with Arcturus, Spica, and Cor Caroli, this star forms a giant asterism called the Diamond of Virgo.

Algeiba (Gamma Leonis) is a famous double star whose name was derived from the Arabic al-Jabha, "the forehead." But noted author R.H. Allen remarks in *Star Names: Their Lore and Meaning* that it is located in Leo's mane and offers a clever explanation for this contradiction. He points out that the Latin word for mane is *juba*, which "distinctly appeared" for Gamma Leonis on the charts made by Bayer, Riccioli, and Flamsteed. Allen suggests that Algeiba is Latin, deliberately or unknowingly Arabicized by someone to its present form. However, author George A. Davis, Jr. reasons that Algeiba is indeed located in the forehead of the ancient Arabic Lion, which predated our current Leo in mideastern lands. This ancient Arabic lion, known as Asad, was truly enormous — stretching all the way across the spring sky from Gemini to Libra. One of his front paws lay in Gemini and our diminutive Leo composed his head.



Zosma (Delta Leonis) means "loincloth" in Greek. Allen mentions that Ulug Beg, a grandson of the Emperor Tamerlaine, called the star Al Thahr al Asad, "the Lion's Back."

Algenubi (Epsilon Leonis) is derived from a phrase meaning "the southern star in the Lion's head." If we use this name for Epsilon, then only Eta Leonis is without a proper name in the Sickle.

Adhafera (Zeta Leonis) means "coil" or "plait" of hair, originally referring to the lion's tail. Perhaps the name was also accurate for the curling hair of the Lion's mane where Zeta Leonis is found.

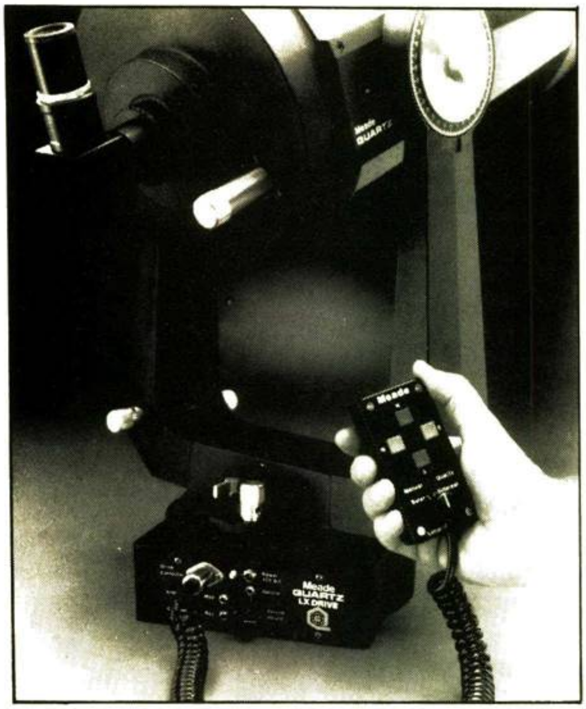
Chort (Theta Leonis) is derived from an Arabic term for "the two short ribs."

Al Minhar (Kappa Leonis) is a title no longer used, but means "the nose" — an accurate assessment of the star's position on many drawings of the Lion.

Alterf (Lambda Leonis) comes from the Arabic meaning "eye" or "glance" of the Lion. Its location on Ptolemy's map, as in most modern depictions, is on the Lion's mouth.

Rasalas (Mu Leonis) is a contraction of the Arabic phrase for "the lion's head."

Subra (Omicron Leonis) is a name rarely found in modern star catalogues. Omicron Leonis is dim, but lies interestingly positioned on a line between Regulus and Hydra's head. Unfortunately, the name comes from al Zubra, "the mane," which would be inappropriate for both ancient Greek and Arabian lions. But the name Zubra has also been used for Delta Leonis — where it makes sense if we are picturing the ancient Arabian lion, Asad.



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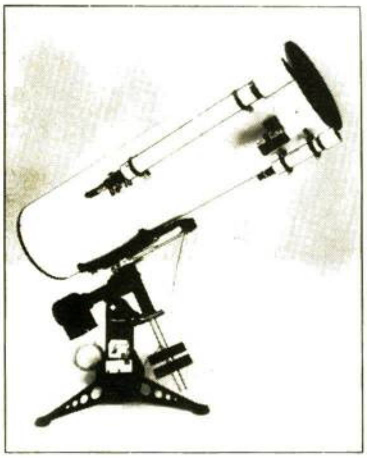

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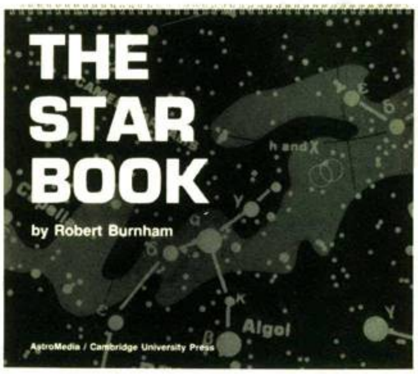
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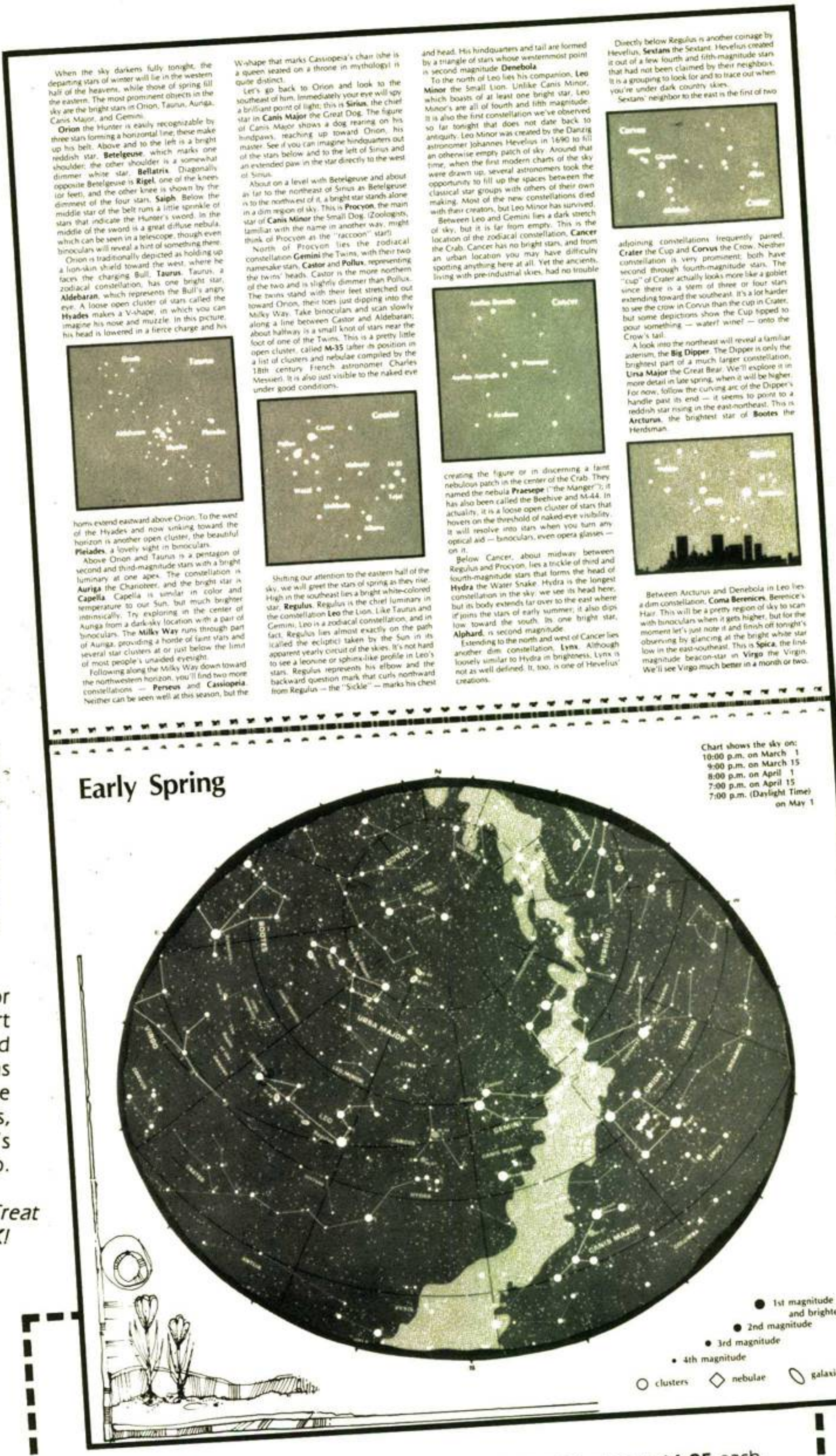
Early Spring
Chart shows the sky on:
10:00 p.m. on March 1
9:00 p.m. on March 15
8:00 p.m. on April 1
7:00 p.m. on April 15
7:00 p.m. (Daylight Time) on May 1
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
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Equipment Atlas

Build a $6 Eyepiece Warmer

by
Lee Keith

Nothing is more annoying than venturing outside to observe, setting up your telescope, checking that everything is running properly, experiencing a lovely twilight, and then being soaked by dew when nightfall finally comes. You might think of building a dewcap — a shield for isolating vulnerable parts of the telescope like the front objective lens or corrector plate. But even a long dewcap's protection usually lasts only minutes, especially during extreme humidity. Is there *anything* you can do about the problem of dew?

Dewing occurs on surfaces that cool below the dew point, the temperature at which evaporation no longer occurs. This causes water droplets to condense on anything at or below that temperature. A glass of ice water on a hot day provides an excellent example: the air next to the glass is cooled to its dew point, so water in the air condenses and drips down the glass.

Each optical element has its own particular susceptibility to dew. On refractors, the objective lens and the eyepiece are equally vulnerable. With reflectors, the mirror is nearly impervious to dew inside the tube, which acts like a giant dewcap. A reflector's secondary mirror, however, can become coated with moisture in only a few minutes. With Schmidt-Cassegrains or other catadioptric scopes, the fragile front corrector plate usually dews up very quickly.

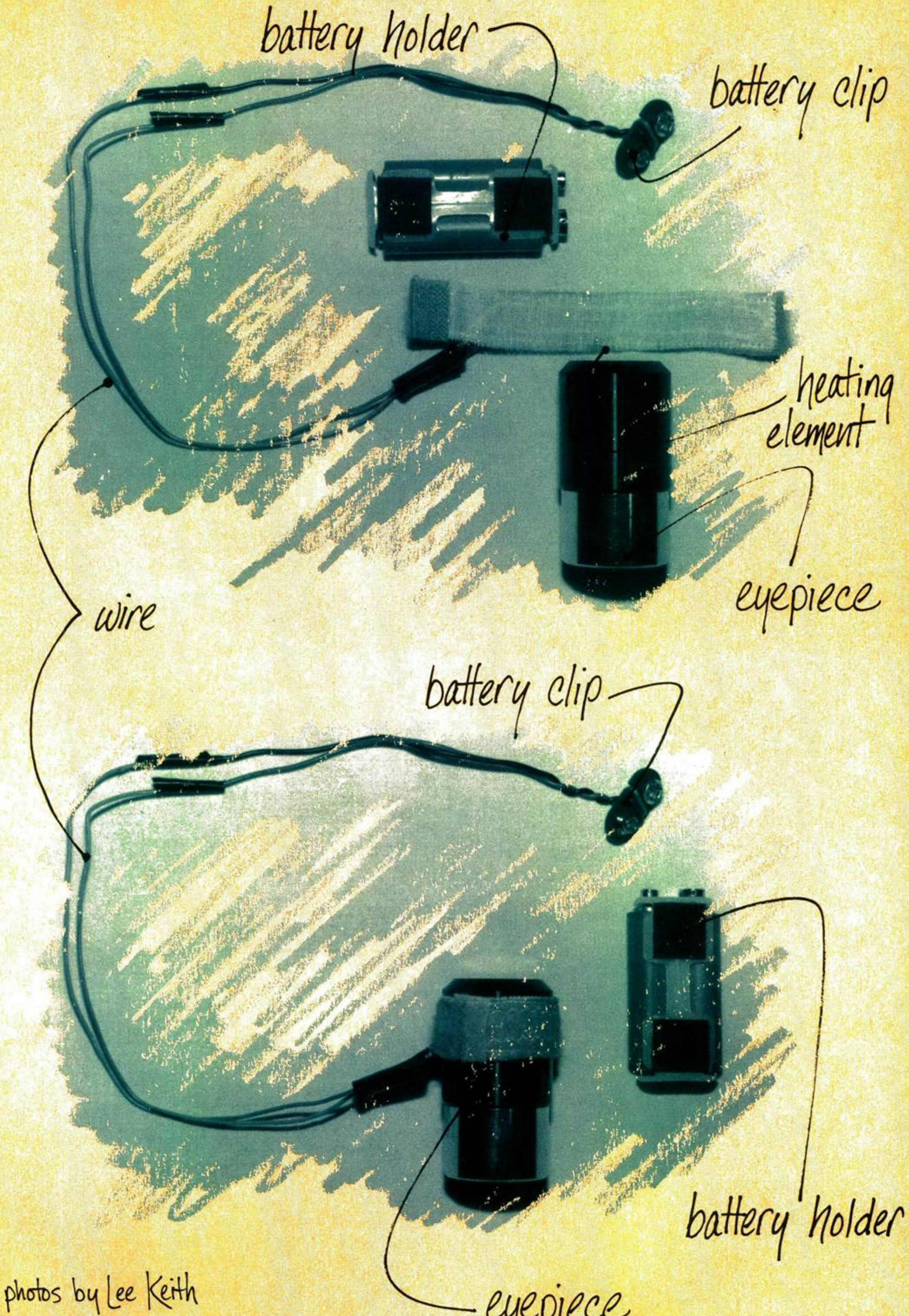
Dewcaps can help slow down the formation of dew — but they don't prevent it. The key to preventing annoying dew is keeping the telescope's temperature slightly above the dew point. Realizing this, and living in the midwest where dew is prevalent, I decided to build a simple heating element which has since eliminated the problem.

The materials you'll need to build your own heater are easily available. The most obscure item is nichrome heating wire.

photo by Jack Newton

Materials:

- 4 ½″ x ½″ length of fabric
- 1 AA battery holder with 9-volt clip
- 2 AA batteries
- 1 9-volt battery snap with leads
- 10″ nichrome heating element wire
- Light-gauge wire, as needed
- Electrical tape
- Soldering gun and solder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wire
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photos by Lee Keith

The heating system installed on a Newtonian reflector.

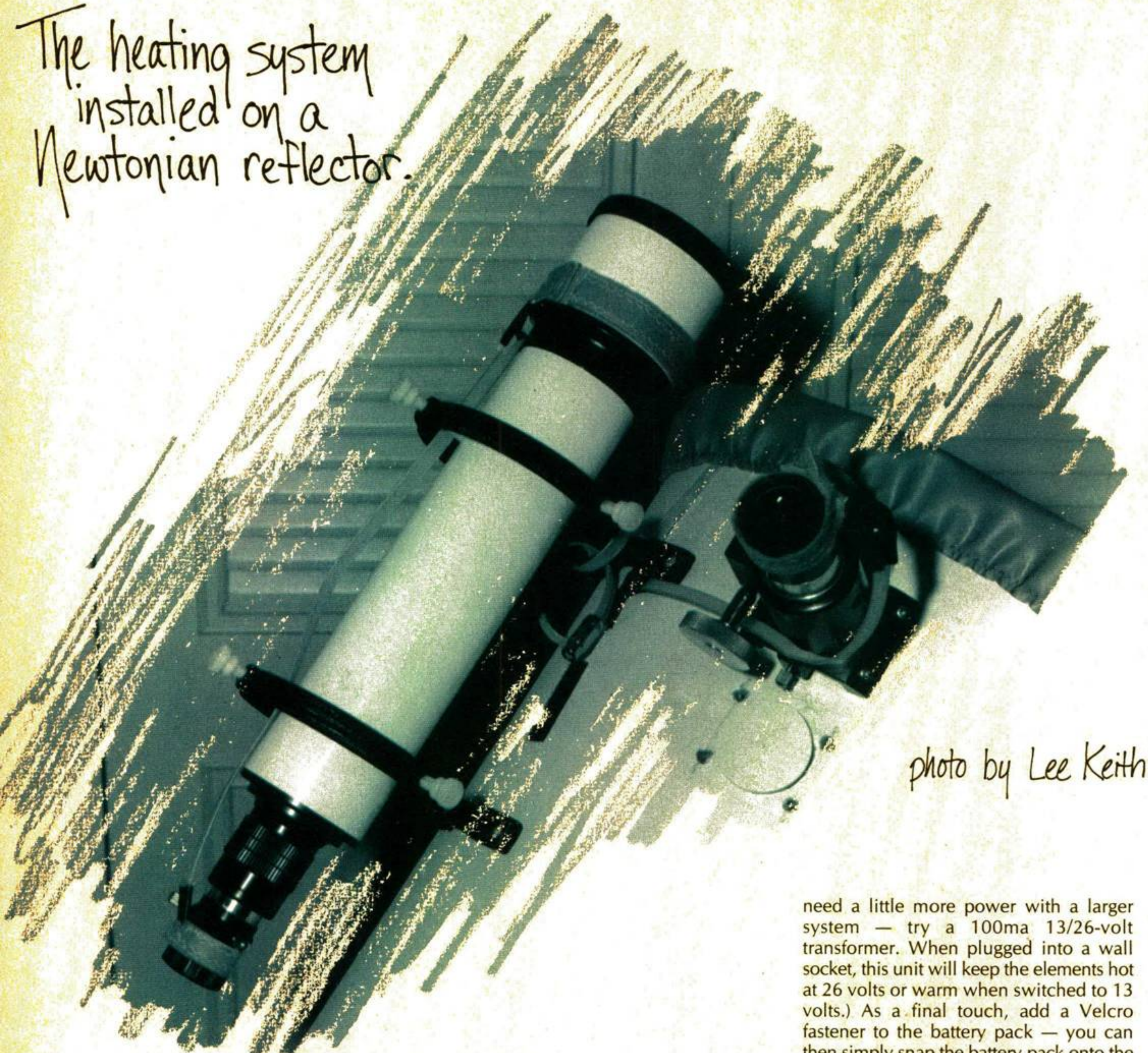

photo by Lee Keith

You can find it at a science supply or surplus store — or you can cannibalize an old hair dryer. The wire should be small enough that it can be easily wrapped around an eyepiece or lens. The other materials are commonly found (see box). In fact, the entire cost of an eyepiece heater is less than $3. If you want to heat your finder, diagonal, or objective, the cost escalates to a heady $6. Yet this small investment will save you many nights of ruined observing!

First, you need a power supply. This is easily made with two AA (penlight) batteries placed in a battery holder, which is attached to a 9-volt clip. By using the battery clip as a switch, you can avoid installing a normal toggle switch. The two wires from the battery clip are then soldered to a length of nichrome wire long enough to encircle an eyepiece twice. Next, sew the nichrome wire to a piece of fabric (I used felt) that has Velcro pads attached to hold the wire around the eyepiece. On a larger scale, you can make a fabric wrapper for your entire tube, sew the nichrome wire onto it, and protect the entire telescope from dew. (You might need a little more power with a larger system — try a 100ma 13/26-volt transformer. When plugged into a wall socket, this unit will keep the elements hot at 26 volts or warm when switched to 13 volts.) As a final touch, add a Velcro fastener to the battery pack — you can then simply snap the battery pack onto the tube. The two AA batteries will keep your eyepiece warm for about three hours of continuous use. Don't hesitate to unsnap the battery pack periodically to extend its lifetime.

Those of you who are willing to spend $6 and the time can dew-proof your telescope. This setup has allowed me to get more observing done, and it was so easy that the hardest part was deciding where to stick the wires so they stayed out of the way!

Lee Keith is a computer programmer for Micro Management Systems, Inc. He uses 6-inch and 10-inch reflectors for deep-sky observing, and is an avid telescope maker.

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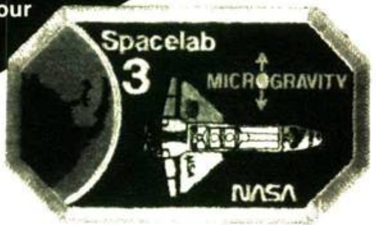

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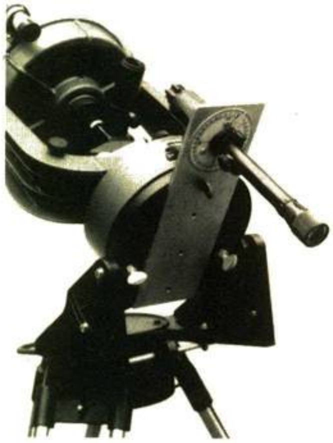

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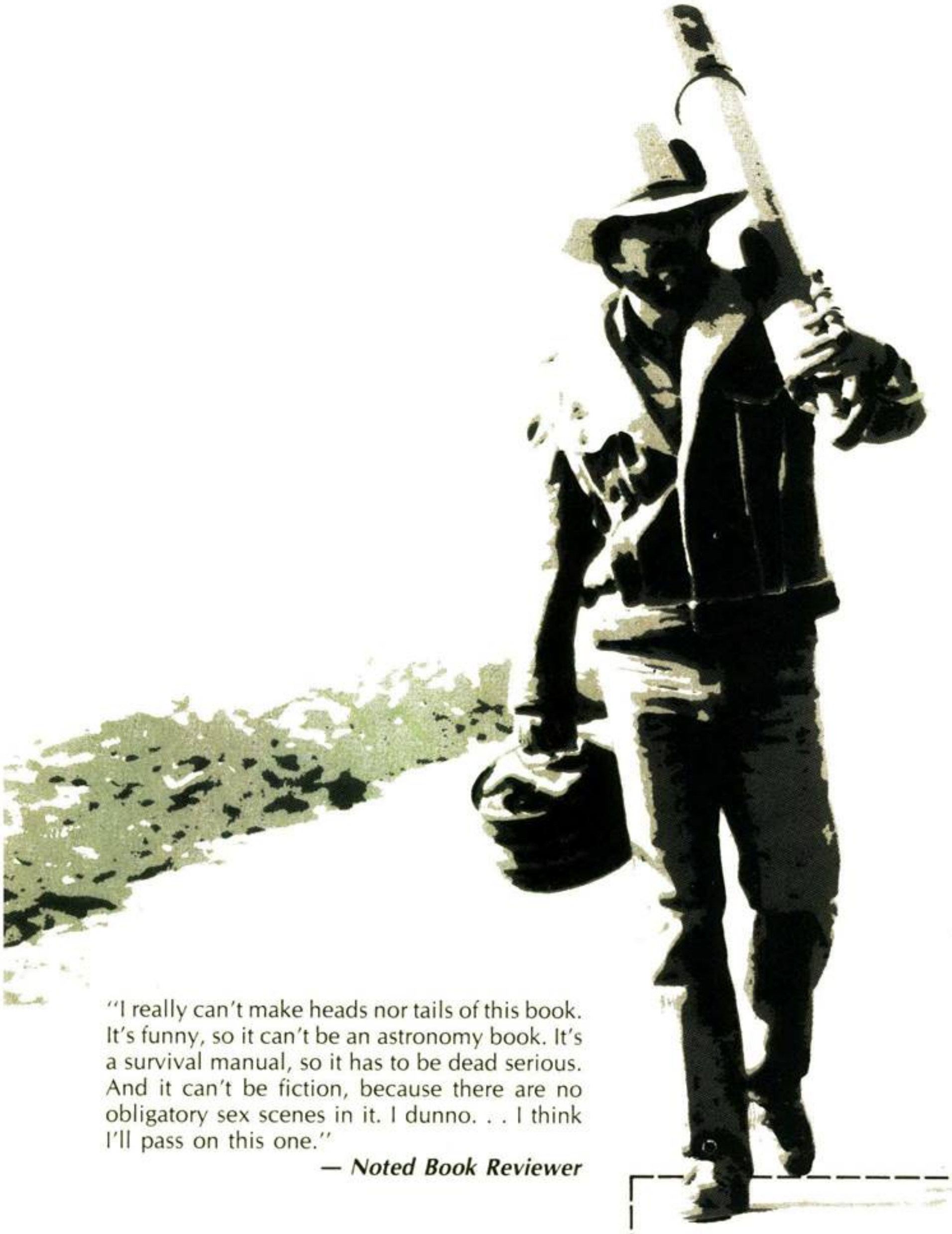

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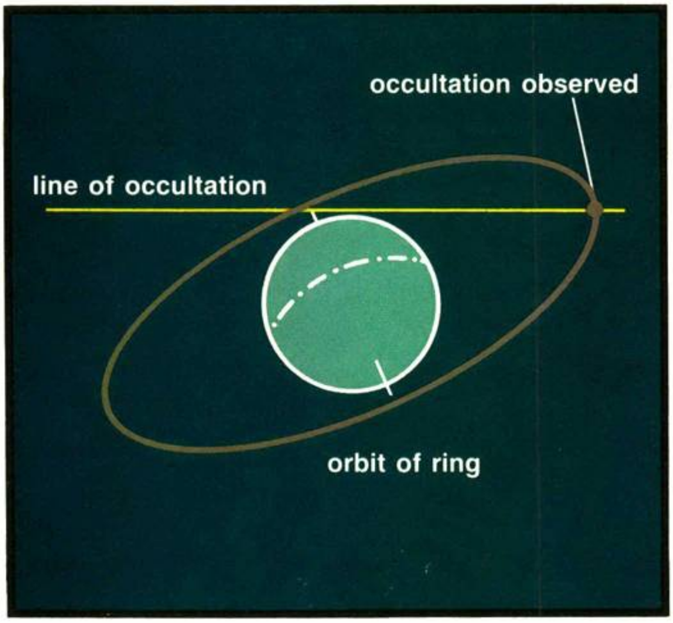

"Ring" Discovered Around Neptune

Ever since the discovery of Uranus' ring system in 1977, astronomers have considered the possibility that Neptune may also harbor rings. Early in January, the University of Arizona announced that a team of American and European astronomers had indeed discovered a single, lopsided "ring" around Neptune from data collected during an occultation of the planet on July 22, 1984. The researchers were led by William B. Hubbard of the University of Arizona's Lunar and Planetary Laboratory and Andre Brahic of the University of Paris.

Ironically, the July occultation was initially of little interest to others searching for a neptunian ring or rings. Said Hubbard, "There was a last minute prediction that [the background star] was going to miss Neptune, so many people lost interest in it." Hubbard's team was stationed at the 0.9-meter telescope at the National Optical Astronomy Observatories' Cerro Tololo Inter-American Observatory, high in the mountains of Chile. At the same time, about 60 miles north, Brahic's group viewed the occultation with a 1-meter telescope and a 0.5-meter telescope at the European Southern Observatory.

At 5 hours 40 minutes Greenwich time on July 22 — just as the occulting planet approached the position intersecting the line of view between Earth and the star — telescopes recorded a duration of about one second when infrared wavelengths of light reaching them dimmed by some 35%.

The Hubbard observers, graduate student Faith Vilas (of the Lunar and Planetary Laboratory) and L. Elicer of the Cerro Tololo staff, were unable to see the brief event on the computer printout their telescope generated every 3.4 seconds. Vilas returned to Tucson with the printout and a magnetic tape of the observation — a record of data made at 1/100-of-a-second intervals.

Brahic's group included Patrice Bouchet of the European Southern Observatory; Bruno Sicardy and Francoise Roques of the University of Paris and the Observatory of Paris; J. Manfroid of the Institute of Astrophysics in Liege, Belgium; and R. Hafner of the University of Munich. This group *did* record the star's brief dimming in their data. They reported it at the Division of Planetary Sciences meeting in Hawaii last October.

Their report prompted Hubbard to check his magnetic tape of data on a computer. When he saw the same event for the same time for the two observatories 60 miles apart, "I nearly fell out of my chair," Hubbard said. He called Brahic shortly before Christmas to confirm that the occultation event was caused by a ring segment, not a satellite. They calculate the ring fragments' size as 10 to 15 kilometers wide and about 100 kilometers long. It is three Neptune radii, or 70,000 to 80,000 kilometers, from the planet.

This neptunian ring appears to be fragmented and completely unlike the rings of Jupiter, Saturn, and Uranus. It is especially strange because it lies in a zone beyond the "Roche limit." Material inside this limit is in a kind of "frozen state of formation," according to Brahic, because the gravitational pull of the planet prevents small pieces of matter from accreting into larger bodies. Larger planetary satellites, held together by their own gravity, orbit outside this limit. Why the segmented ring of Neptune lies beyond the Roche limit is a mystery.

This discovery is critical to the Voyager mission, which will flyby Neptune in 1989. As the spacecraft is programmed now, it will head directly for Neptune's ring plane as it flies to rendezvous with the planet's great moon Triton. Voyager may well need a new set of instructions to survive.

Astronomers determined to observe future occultations of Neptune's fragmented ring "will be like gamblers," Brahic said. "If the ring is broken, some will see it and some will not. Some will win, some will lose." Hubbard is re-checking data collected during earlier searches for Neptune's ring by scientists who may have been, without realizing it, "winners."

During one of the first major searches for neptunian rings in 1981, Hubbard and University of Arizona colleagues Larry Lebofsky, David Tholen, and Harold Reitsema observed an eight-second occultation event around Neptune using a 1.5-meter telescope on Mt. Bigelow and a 1.5-meter telescope on Mt. Lemmon in the Santa Catalina Mountains north of Tucson. According to Hubbard, another segment of Neptune's ring might have caused that event.

Hubbard is also checking observations made by Lunar and Planetary Laboratory scientist Tom Gehrels at Hobart, Tasmania, in June 1983. He observed a single event that dimmed the starlight by 2.5% and lasted about 27 seconds.

"Quasar-like" Objects Nearby

The discovery of a new class of celestial radio sources in the Milky Way Galaxy may provide important clues to how distant quasars work. These newly found objects are about 20,000 light-years from Earth — tens of thousands of times closer than the nearest-known quasar, which is more than a billion light-years away. Although they are *not* quasars, their behavior may shed light on how quasars work.

The discovery was made by David Helfand, associate professor of physics at Columbia University and Robert Becker, assistant professor of physics at the University of California at Davis. Their find is the cover story of the January 10, 1985 issue of *Nature*.

Helfand and Becker made their discovery while using the Very Large Array radio telescope in New Mexico to study debris from exploded stars — supernova remnants — known to exist in or near the galactic plane. The scientists found that two of the objects previously catalogued as such remnants are, in the words of the study, "representative of a new class of nonthermal radio sources . . . formed through the emission of relativistic particles produced by high-velocity accreting binary systems."

According to Helfand, the newly-found systems resemble the most popular quasar model. If this is borne out by additional confirming observations, the new sources will provide astronomers with the long-sought opportunity to study the processes within quasars, among the most distant and enigmatic structures in the universe.

Each of the newly found objects appears to be powered by a collapsed star — a black hole or neutron star — only a few miles in diameter but with enough gravity to

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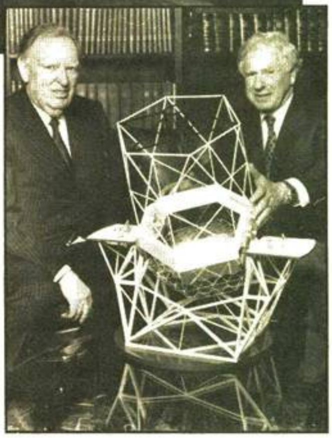
ASTRO NEWS

strip material from a normal star orbiting around it. The stripped-off material forms a ring-like accretion disk around the collapsed star's equator, and the energy released as this material falls onto the smaller object powers relativistic particle beams.

These jets shoot out from the collapsed star's polar regions and spiral through the interstellar magnetic field. The new sources appear to be less than a million years old, although the total energy in the ejected electrons is equivalent to that released by the Sun during its five-billion-year existence. The jets become detectable because the electrons emit radio waves. The resulting cloud-like formations — one resembles a bird in flight and the other a tornado — trail behind the bright point of radio emission that is the collapsed star and its companion. The objects were first discovered in March 1984 and radiographs (computer-processed pictures of the system's radio emissions) were made in September.

Of their relation to quasars, Helfand says: "In those systems [quasars], a collapsed star is likely to have the mass of millions of normal stars, and whole stars are swallowed to provide the energy required. These new sources, relatively close to home as they are, may offer an opportunity to study the processes occurring in quasars in greater detail than is possible for those very distant objects."

Caltech to Build 10-Meter Telescope



The California Institute of Technology is planning to build the world's largest telescope — an instrument with an aperture of 10 meters to be sited atop Hawaii's Mauna Kea. A $70 million grant from the W.M. Keck Foundation of Los Angeles will make the project possible. Construction of the W.M. Keck Observatory, as the facility is to be called, will begin in 1986 and scientific observation is scheduled to start in 1992.

The primary mirror of the Keck telescope will have a diameter of 10 meters (about 400 inches), making it the largest optical telescope in the world — four times more powerful than the 5-meter Hale telescope on Palomar Mountain, also owned and operated by Caltech. The Hale telescope ranked as the world's largest from 1948 to the late 1970s, when the Soviet Union began operating a 6-meter telescope. Construction of a 10-meter instrument has only recently become possible following the development of unique technology by University of California (UC) scientists at the Lawrence Berkeley Laboratory.

Besides the Keck Telescope, the W.M. Keck Observatory will include computer rooms, electronic shops, mechanical shops, mechanical equipment, mirror aluminizing facilities, a control room, coude room, storage space, staff facilities, and a visitors' gallery. Total cost for the Keck Observatory will be about $85 million.

The proposed grant, which would be the largest private gift ever made for a scientific project, was announced January 3. Howard B. Keck, president of the W.M. Keck Foundation, said: "This proposed grant is historic in both its size and purpose. The Keck 10-Meter Telescope will enable us to see much farther than we can see today and help to discover how the universe began."

Keck added, "As a California-based foundation we are particularly pleased to be involved in a project that will guarantee that California scientists at Caltech and UC will continue to lead the world in the field of astronomy. Astronomers expect the 10-Meter Telescope to be at the forefront of optical astronomy for many decades into the 21st century."

Caltech president Marvin L. Goldberger stated, "On behalf of the entire scientific community, we applaud the vision of the W.M. Keck Foundation directors in offering to make this historic grant. Scientists will use the Keck Telescope to provide answers to the most challenging and basic questions of the universe. It will enable astronomers to look back in time to within only a few billion years of the 'Big Bang' origin of the universe — billions of years earlier than is possible with existing optical instruments."

Goldberger continued, "Among the questions to be explored are: how the universe originated; whether or not the universe is continually expanding or will ultimately fall back on itself; why and how galaxies and stars formed and evolved; and how the four basic forces of nature controlled the early history of the universe."

Dr. David P. Gardner, president of the University of California, commented, "The generous gift proposed by the Keck Foundation promises to move astronomy research to new plateaus. The anticipated partnership between two of the finest scientific institutions signals many years of stimulating inquiry ahead, from which worlds of fresh knowledge will result. . . . We in the University of California look ahead with excitement and anticipation to one of history's boldest scientific ventures."

Goldberger also announced that negotiations are under way between Caltech and the University of California for joint operation of the Keck Observatory. Caltech will provide funds for construction of the observatory, while the University of California will contribute toward continuing operation of the facility. Goldberger noted that the site in Hawaii, among the best in the world, is made possible through the cooperation of the University of Hawaii, owner of the property. University of Hawaii scientists will also have access to the Keck telescope.

Behind the instrument is a new technology. Since 1977, UC scientist Jerry Nelson has been developing a segmented-mirror design to be used for the Keck Telescope. With the mosaic mirror, consisting of 36 mirrors which are each 1.8 meters wide and 7.5 centimeters thick, satisfactory performance can only be obtained with a computer-controlled mirror adjustment system. The planned control system is capable of making adjustments on the order of a few millionths-of-an-inch 300 times each second.

The UC scientist has also developed a "stressed mirror polishing technique" to produce the non-axisymmetric surfaces of the hexagonal mirrors. This technique takes advantage of the ease with which opticians polish spherical surfaces. It involves applying a precise force to the mirror blank to warp it. The mirror blank is then polished to a spherical surface and when the applied force is released, the mirror elastically assumes the desired non-axisymmetric surface.

These mirrors allow a much lighter support structure, so at 158 tons the Keck Ten-Meter Telescope will weigh less than one-third the 200-inch Hale Telescope. The new UC design features a shorter focal length, decreasing the length of the instrument to 22 meters (about 72 feet). This reduces the required dome size to roughly that of the Hale Telescope.

The current generation of large telescopes has revealed a stunning array of celestial phenomena over the decades. However, for each question answered by these discoveries many more are raised. The light from distant stars, the intricate structures of quasars and galaxies, the dark clouds of gas and dust in our galaxy, and the center of our galaxy — the Milky Way — hold countless mysteries to be probed.

The Keck telescope, with its 10-meter reflecting mirror, is double the size of the 200-inch Hale Telescope and will provide a fourfold increase in light-gathering power, allowing astronomers to study a volume of astronomical space eight times greater than at present. Such an increase will enable astronomers to see farther into the universe than any ground-based telescope has allowed. At these immense distances, astronomers will be able to study infant galaxies, investigate the nature of quasars, and study in detail the primordial clouds of gas and dust that were the birthplace of the universe.

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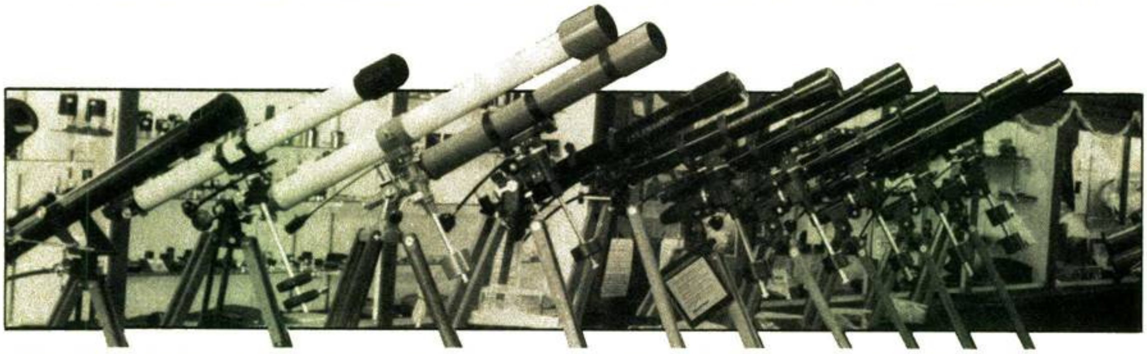

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April 12-13
1985 Southwestern Association of Planetariums Conference, Fort Worth, Texas. Contact: Michael P. Walker, Noble Planetarium, Fort Worth Museum of Science and History, 1501 Montgomery St., Fort Worth, TX 76107. Phone (817) 732-1631, ext. 409.

April 18-21
National Convention of the National Science Teachers Association, Cincinnati, Ohio. Contact: NSTA, 1742 Connecticut Ave. N.W., Washington, DC 20009.

April 20
39th Annual Convention of the North Central Region of the Astronomical League, Fermi National Accelerator Laboratory, Batavia, Illinois. Contact: Deena R. Joslin, 1985 NCRAL Convention Chairman, 959 W. Ogden Ave., Naperville, IL 60540. Phone (312) 355-5357.

April 26-28
Fourth Annual Space Development Conference, Shoreham Hotel, Washington, D.C. Contact: Fourth Annual Space Development Conference, Suite 205, 2400 E. Devon Ave., Des Plaines, IL 60018. Phone toll-free (800) 323-5155; in Illinois (312) 299-3131.

April 27
Family Astronomy Day, Custer Institute, Southhold, New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, NY 11721. Phone (516) 757-7501.

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Astronomy Day. For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985.

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May 2-4
MAPS '85 (Middle Atlantic Planetarium Society), Hayden Planetarium, New York City, New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, NY 11721. Phone (516) 757-7501.

May 15-19
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: TSP '85, Dept. A, 128 N. Commerce, Burleson, TX 76028.

May 17-18
Burke Lake Telescope Meet, Burke, Virginia. Contact: John S. Huggins, 5608 Flag Run Dr., Springfield, VA 22151.

May 22-24
IAPPP Big Bear Symposium, Camp Oaks, Big Bear, California (same location as Riverside Telescope Maker's Conference). Contact: Rev. Donald L. Rohe, 957 W. Marshall Blvd., San Bernardino, CA 92405. Phone (714) 383-4731 or (714) 883-7923.

May 24-27
Riverside Telescope Maker's Conference, Camp Oaks, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92505. Phone (714) 689-6893.

May 25-29
Planetarium Association of Canada Biennial Conference, Toronto, Canada. Contact: Chris Sasaki, McLaughlin Planetarium, 100 Queen's Park Crescent, Toronto, Ontario, Canada M5S 2C6.

June 7-8
15th Annual Apollo Rendezvous and Telescope Fair, Dayton, Ohio. Contact: Chairman, Apollo Rendezvous, P.O. Box 20268, Dabel Branch, Dayton, OH 45420.

June 9-12
Southeastern Planetarium Association Annual Conference (professional conference), Land Between the Lakes, Kentucky. Contact: Doug Gegen, Visitor Center, Land Between the Lakes-TVA, Golden Pond, KY 42231. Phone (502) 924-5602.

June 17
3rd American Workshop on Cometary Astronomy, Tucson, Arizona. Contact: Steve Edberg, Jet Propulsion Laboratory, 4800 Oak Grove Dr., T-1166, Pasadena, CA 91109.

June 17-22
ALCON '85, Tucson, Arizona. Contact: Shelley Fleischman, c/o Venture Travel Inc., 6709 E. Camino Principal, Tucson, AZ 85715.

June 23-27
Astronomical Society of the Pacific Meeting, Flagstaff, Arizona. Contact: Andrew Fraknoi, A.S.P., 1290 - 24th Ave., San Francisco, CA 94122. Phone (415) 661-8660.

June 28-30
IAPPP Summer Workshop, Flagstaff, Arizona. Contact: Robert Fried, Braeside Observatory, P.O. Box 906, Flagstaff, AZ 86002. Phone (602) 774-1249.

June 28-July 1
Royal Astronomical Society of Canada General Assembly, Edmonton, Alberta, Canada. Contact: RASC, Edmonton Centre, c/o Edmonton Space Sciences Centre, 11211 - 142 St., Edmonton, Alberta, Canada T5M 4A1.

July 11-14
The Study of Variable Stars Using Small Telescopes (symposium), University of Toronto, Toronto, Ontario. Contact: Dr. John R. Percy, Department of Astronomy, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

July 15-20
Spaceweek UPstate 85, Haywood Mall, Greenville, South Carolina. Contact: PAS, P.O. Box 197, Fair Play, SC 29643-0197.

July 15-24
International Space Week '85, Cocoa, Florida. Contact: James B. Harris, Jr., Director, Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.

July 15-August 2
Astronomy Institute for Pre-College Teachers, The University of Texas at Austin, Austin, Texas. Contact: Mary Kay Hemenway, College of Natural Sciences, The University of Texas at Austin, Astronomy Department, RLM 15.308, Austin, TX 78712. Phone (512) 471-4461 ext. 307.

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1985 Summer Institute, sponsored by Spitz Space Systems, Inc. Contact: Mona E. Coldiron, 1985 Summer Institute, Spitz Space Systems, Inc., P.O. Box 198, Chadds Ford, PA 19317.

August 9-11
STARFEST '85, The River Place Campground, Mount Forest, Ontario, Canada. Contact: Andreas Gada, 145 St. George St., Apt. 701, Toronto, Ontario, Canada M5R 2M1

August 17
Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.

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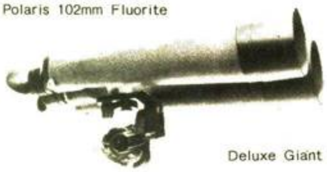

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Cold Dark Matter and the Origin of Galaxies

by Ann K. Finkbeiner

Galaxies are scattered all over the universe — clustered in knots, strewn in superclusters, or whirling alone through space. They are undeniably ancient, but cosmologists do not know how they were born.

Any model that explains how galaxies form must take into account certain observations. The first is the immense age of galaxies. Astronomers infer age from distance, from a Doppler-shifting of the galaxies' light toward the red end of the spectrum. The earliest visible objects that can be counted as galaxies are distant, brilliant points of light called quasars. The spectra of both quasars and galaxies share lines characteristic of the same elements. The big difference is that the lines for quasars are enormously redshifted. This means the oldest quasars originated billions of years ago — most of the way back to the Big Bang, at least. And even then they were already old: the lines in quasars' spectra are those of heavy elements, which had to be created by previous generations of stars. So the quasars may be children of galaxies older still — probably by several billions of years. Whatever model of galaxy formation cosmologists settle on, it must create galaxies relatively soon after the beginning of the universe.

The second observation to account for is the extreme uniformity of conditions from which galaxies were born. For 100,000 years after the Big Bang, the universe was a smooth hot soup of matter and radiation. The radiation was so hot that whenever gravity attempted to pull matter together into clumps, high-energy photons immediately blew them apart before they even formed. The effect was a chaotic but smooth distribution of matter and photons, both at the same temperature. The universe cooled as it expanded, however, and after several hundred thousand years, photons no longer had the energy to prevent the formation of clumps. At this point, called decoupling, gravity began pulling little fluctuations of density and clumps of matter together into bigger ones. The radiation continued to cool with the expanding universe; we see it now as the background wash of microwaves at 3° Kelvin that comes from all over the sky.

The 3 K background is the signature of conditions at the point of decoupling. Any fluctuation in this background could be the seeds from which galaxies grew. The most recent measurement of density fluctuations in background radiation, made by David Wilkinson and colleagues at Princeton University, shows nothing stronger than 2.5 parts in 100,000. The difficulty here is that no galaxy could grow from a fluctuation that small — even given the 15 billion years since creation. Cosmologists call this the "smoothness problem."

The third observation is the way galaxies are distributed across the sky. Galaxies seem to occur most often in clusters with other galaxies and less often in isolation. Clusters themselves seem to occur in gigantic superclusters stretching across millions of light-years. Occasionally the neighborhood of superclusters contains huge voids — space that is empty of anything obvious. Using a statistical measure called a correlation function, James Peebles of Princeton University confirmed that galaxies were indeed most likely to be found in the neighborhood of other galaxies. Any model of the origin of galaxies must take into account all these observations and must reproduce the sky we now see.

In the early 1970s, Peebles proposed a model of galaxy formation he calls the bottom-up theory: galaxies formed first, collected later into clusters, which in turn gathered into superclusters. Peebles' theory could account for the age of galaxies, but left the smoothness problem — that gravity worked too slowly to form galaxies, let alone clusters or superclusters — unsolved.

Around the same time, Yakov Zel'dovich of the Institute for Applied Mathematics in Moscow suggested an opposite approach, the top-down theory: galaxies occur in clusters because they were born there; superclusters form as huge flat "pancakes," fragmenting first into clusters, then individual galaxies. But this theory met neither the constraints of age nor smoothness. The universe wasn't old enough for such fragmentation to take place — and besides, galaxies are almost certainly older than clusters and superclusters, which appear to be falling together only now.

Near the end of the 1970s, Zel'dovich suggested an ingenious solution for the smoothness and age problems: find some kind of particle that never participated in the primordial thermal equilibrium — or, if it did, that decoupled before photons did. Under the influence of gravity, those particles could collect into paths or ravines. Then at decoupling, when matter and photons were free to go their separate ways, matter would be attracted to the pre-existing gravitational ravines and fall into them readily. In this new model, the photons would remain undisturbed, the microwave background would show no fluctuation, and the pancakes — now given a head start — would have time to grow.

For a few years, the most popular candidate particle for Zel'dovich's theory was the neutrino. The neutrino, a product of radioactive decay, exists in numbers so huge that they outnumber all other particles. It would have decoupled well before the photon. But there's a catch: Zel'dovich's ingenious suggestion hinges on the neutrino being subject to gravity, therefore having mass. Though physical theory neither requires nor excludes a mass for the neutrino, experimenters looking for a mass for the neutrino have had no success.

Furthermore, in 1983, Adrian Melott at the University of Pittsburgh and Joan Centrella at the University of Illinois, and Simon White, Marc Davis, and Carlos Frenk at the University of California at Berkeley independently ran extensive computer simulations of the evolution of a universe dominated by massive neutrinos. The simulations showed the structure Zel'dovich had predicted, but superclusters came out much denser and the voids much emptier than the sky really is. Furthermore, the simulations had galaxies forming much too late. Making pancakes with neutrinos still doesn't give the universe enough time.

But rather than discarding Zel'dovich's suggestions totally, cosmologists looked for a different candidate particle. They found several, which they collectively called "cold dark matter." Cold dark matter includes photinos, gravitinos, and axions — all hypothetical particles derived from various physical theories that attempt to unite the basic forces of nature.

Hypothetical or not, cold dark matter seems to do the trick. Like neutrinos, it should exist in large quantities and would interact with other matter so rarely as to be effectively invisible. Unlike neutrinos, it certainly has mass — at least theoretically. Theory says it was never in thermal equilibrium with the rest of the universe and was free, therefore, to make gravitational ravines from the very beginning of time. In 1983, Melott and Centrella, and the Berkeley group, ran simulations of the growth of structure in a cold dark universe. These computer runs support Peebles' bottom-up theory: galaxies form immediately, with clusters and superclusters aggregating and coalescing soon after. Better still, the simulations also show a distribution of galaxies that closely resembles the actual map of the sky.

However, there's one outstanding problem with this wonderful material — and cosmologists can only shrug when confronted with it — no experimenter has yet *found* cold dark matter. Worse still, no indispensible theory demands that it must exist! A second problem is that simulations of such a universe, although they reproduce the actual distribution of galaxies well, do not reproduce the voids found in the real sky. The largest void known to date lies in the constellation Bootes and is 60 to 100 megaparsecs across.

David Koo at the Carnegie Institution of Washington and Richard Kron at the University of Chicago, among others, have been charting the extremely distant universe out to distances of thousands of megaparsecs. The models don't match the sky, but despite the mismatch of observation and theory, Koo would not use the data now available on voids to discard the cold dark model for the universe. "It really depends on what you mean by void," he says. "We generally define it statistically. The discoverers of the Bootes void expected to find in that volume of space, 18 galaxies and found none. In the volumes of space we study, we expect to find 10 galaxies and find none. At this point, I'd be more comfortable calling these not voids, but underdensities. If we expect to see 1000 galaxies and find none, that's a void." Simon White, now at the University of Arizona in Tucson, is similarly undeterred by the inability of his simulations to reproduce large voids: "No one's sure enough of their observations of voids to tell us exactly what we're supposed to be reproducing."

The cold dark universe model of 1983 successfully met most of the theoretical constraints: it didn't demand that the microwave background show fluctuations, it got the age of the galaxies right, and it reproduced the observed distribution of galaxies. That same year, however, Neta Bahcall of the Space Telescope Science Institute and Raymond Soneira of the Institute for Advanced Study reported finding another constraint on the formation of galaxies. To confirm clustering, Bahcall and Soneira repeated Peebles' work. But instead of correlating the positions of galaxies to other galaxies, as Peebles had done, they correlated the positions of clusters. They found that compared to galaxies, clusters are 20 times more likely to inhabit each other's neighborhoods. This implies that clustering, as determined by the correlation function, is strongly hierarchical and increases with scale. In short, if galaxies tend to hang out together, clusters tend even more strongly to stick to other clusters.

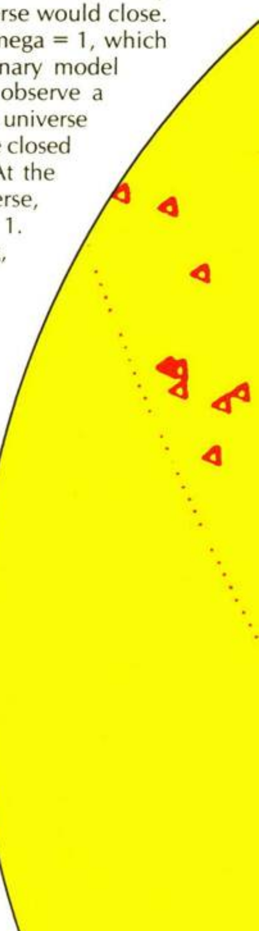
Yet another constraint came from the best current model of the way the universe began, the inflationary model. The inflationary model predicts a certain density for the universe — a prediction White and Davis used in their computer simulation of structure in a universe dominated by cold dark matter. Cosmologists suspect that by using the cold dark matter and this density they can fully explain the hierarchy of clustering and thus the future of the universe.

The future of the universe depends on which is stronger — the push of its expansion outward or the gravitational pull of all its mass inward. The strength of the gravitational pull depends on the amount of mass in the volume of the universe — that is, on its density. If the density of the universe is high enough, gravity wins and its pull will eventually reverse the expansion: the universe will contract and close in on itself. If the density is too low, the universe will expand forever. Which future we get, then, depends on how dense the universe is.

One way astronomers measure density uses the mass-luminosity relationship — the more luminous a galaxy, the more massive it should be. But the mass-luminosity relationship is not precise, it could be off by as much as 40%. In any case, the mass implied by the galaxies' luminosities is 0.01 to 0.02 of the critical density needed to close the universe. Another way to measure density is to calculate the density necessary for the early universe to synthesize helium and deuterium from hydrogen. This way, the density comes out higher — between 0.14 and 0.19 of the critical amount. A third approach is through motion. The way spiral galaxies rotate and the ways galaxies move inside clusters allow calculation of their masses. These "dynamical masses" come to between 0.1 and 0.2 of the critical density. (In all three cases, the fractions are the ratio of the actual density to the critical density, a quantity cosmologists call omega.)

Perhaps the missing mass problem is really a missing light problem

To cosmologists, fractions of 0.1 or 0.2 are uncomfortably near an omega of 1 — which means the universe would close. They have a "philosophical prejudice" for omega = 1, which they justify in three ways. First, the inflationary model predicts an omega of 1; second, while we observe a universe with an omega not much less than 1, a universe with an omega much greater than 1 would have closed long ago; third, omega changes with time. At the much greater densities of the earliest universe, omega would have been much nearer to 1. Specifically, 10^{-43} seconds after the Big Bang, omega would had to have differed from 1 by less than one part in 10^{51}.



Thus a huge amount of mass, around 90 percent of the universe, seems to be missing — or, more strictly speaking, undetectable. What can it be? The mass filling the gap between an observed omega of 0.1 or 0.2 and a hypothesized omega of 1 can be neither luminous nor gravitationally bound to galaxies or clusters, since bright, bound mass is already included in density calculations. Among cosmologists, cold dark matter is a popular candidate for the remainder.

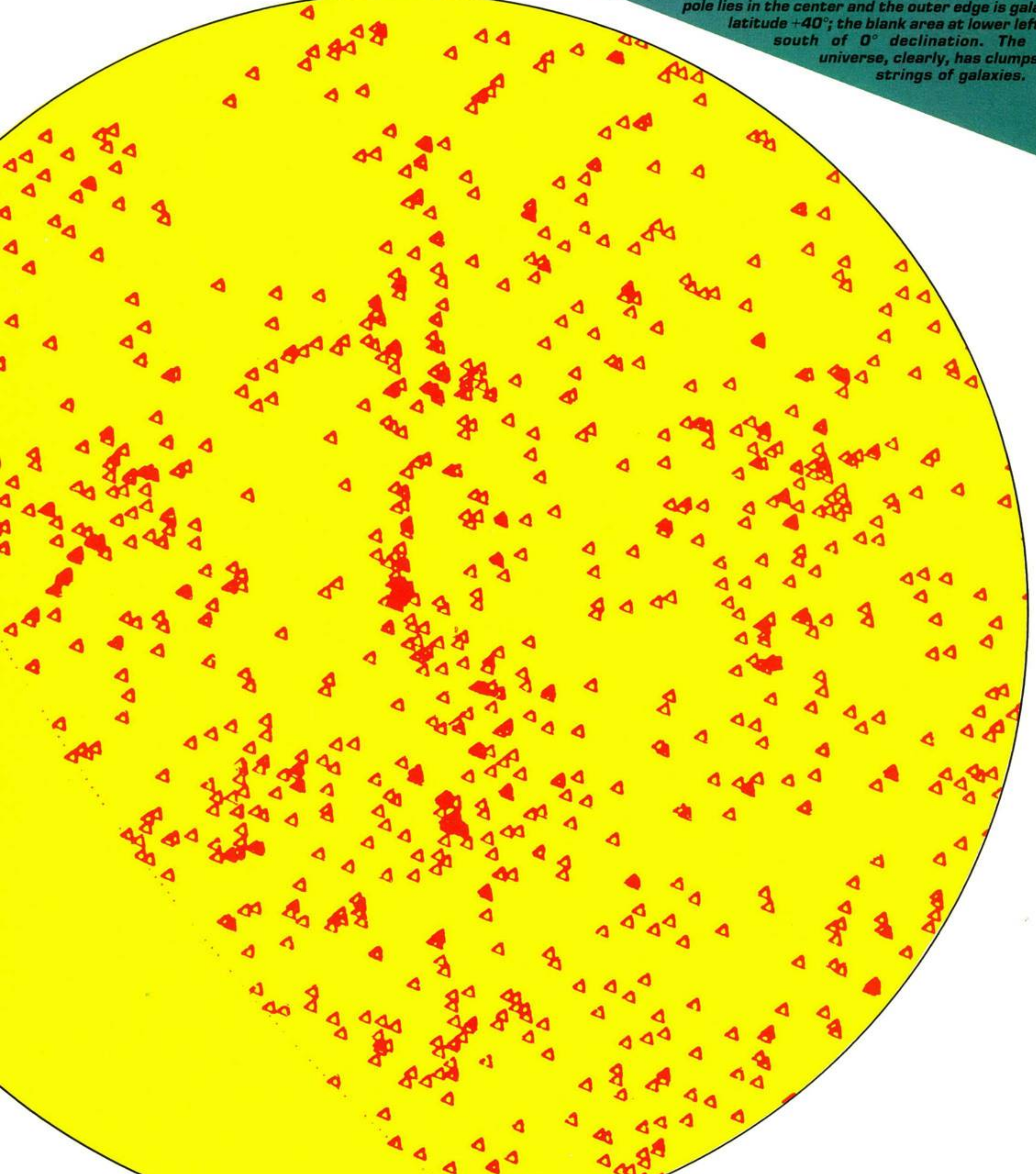
Still, giving the missing mass a name solves only part of the problem. If cold dark matter truly fills most of the universe, where is it? How is it distributed? Does it help galaxies form? And can it explain the hierarchy in clustering? A new idea called biased galaxy formation offers some answers to these questions, but to understand how it works, let's back up a moment.

Perhaps, as Jeremiah Ostriker at Princeton once said, the missing mass problem is really a problem of missing light. If we assume that all the matter in the universe should shine like the matter found in galaxies and clusters, then 90 percent of the *light* is missing. What is so special about matter that glows — the "light matter"?

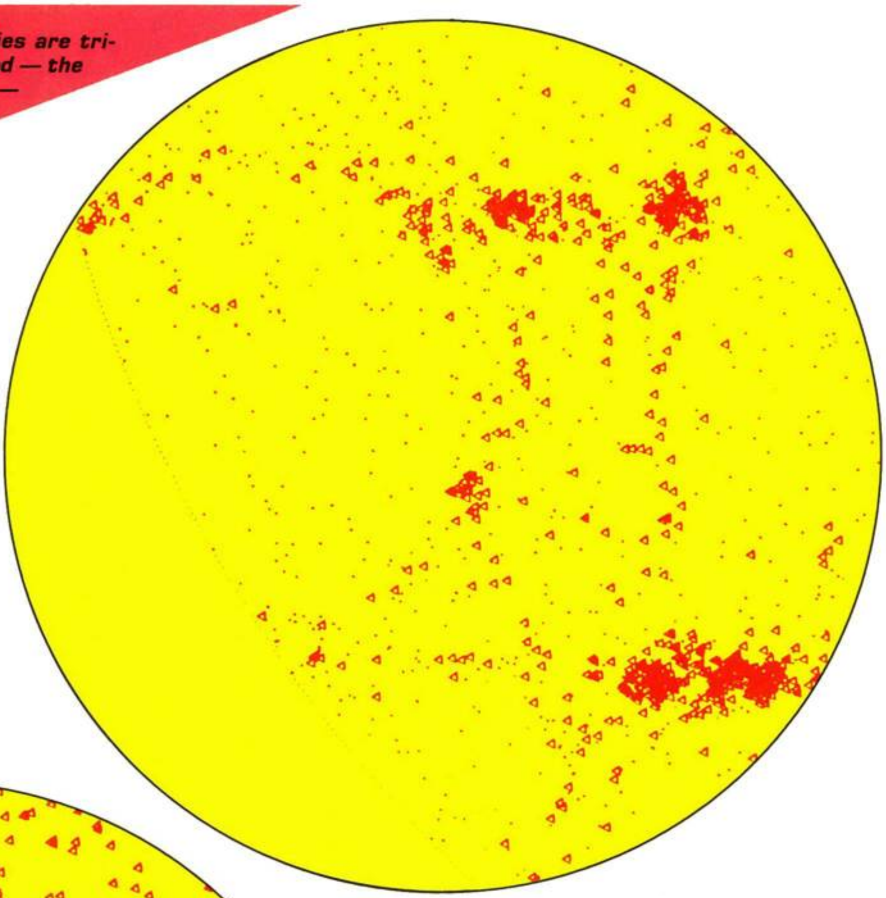
It may be that light matter has no necessary connection to the distribution of dark matter. "It's not clear that light matter directly traces the dark matter," says Simon White. Cosmologists realized that if the dark matter doesn't follow the light, and if it's not bound, then it must be distributed smoothly. "Any smoothly distributed matter," says Peebles, "wouldn't be seen by gravitational measures. It cancels out." According to Nick Kaiser at Berkeley, that, in turn, is a clue to galaxy formation.

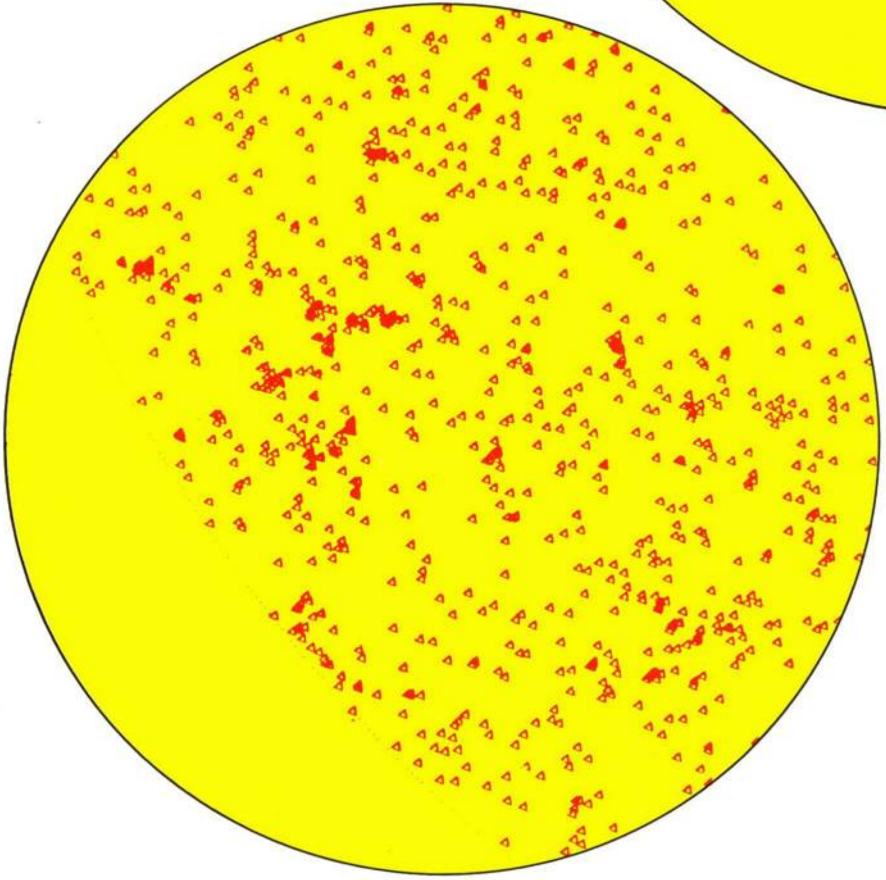
Right from the beginning, it appears the universe was at critical density and filled primarily with cold dark matter. In it, small random ripples or peaks and valleys — densities higher

Every model for the formation of galaxies must eventually confront the real sky! Here we see part of the actual distribution of galaxies in the northern sky — the Milky Way's north pole lies in the center and the outer edge is galactic latitude +40°; the blank area at lower left lies south of 0° declination. The real universe, clearly, has clumps and strings of galaxies.



This model of a neutrino-dominated universe (galaxies are triangles, neutrinos are black dots) doesn't look too good — the clumps are too clumpy and the voids are too empty — when compared with a sample of the real sky (see preceding page).





On the other hand, models that use cold dark matter look much better. Their overall density comes out right and the degree of clumping for the galaxies closely mimics the real universe. (All graphics courtesy of Simon White, University of Arizona; data for the actual sky plot from the Center for Astrophysics Redshift Survey.)

and lower than the average critical density — grew at the same rate. A statistical property of this kind of growth is that high density peaks are most likely to be found near other high peaks. Furthermore, high peaks, being most dense, tend to attract most of the surrounding matter and get higher still. Above a certain height, they grow exponentially in an unstable kind of "runaway."

The highest peaks in density, according to Kaiser, are the sites of clusters where galaxies form more readily and frequently. "Perhaps," says Kaiser, "galaxy formation is much more efficient in areas of over-density." Perhaps galaxies have a bias, and will form only at special places. "Galaxies," states Kaiser, "are rare events."

The best way to look at it is by analogy to southern Arizona," says White. "The land is flat, high desert, except for the mountains. Snow — clusters of galaxies — forms only on the peaks above 7,000 feet. So if you're flying over Arizona, you'll see only the snowy peaks. And you see that the snowy peaks cluster together." The snowy peaks trace the general form of the mountain range: "The distribution of clusters paints a pattern on the large-scale structure," notes Kaiser. But neither the mountain range nor the peaks represent the whole of the universe. The desert is invisible and effectively infinite — thus, biased galaxy formation allows an omega of 1.

Biased galaxy formation also explains Bahcall and Soneira's findings that clustering increases with scale. "They're seeing the peaks of the rich clusters, which are more clustered than the mass in general," says White. Bahcall agrees: "If the correlation function is lower for galaxies than it is for clusters, then it could be lower yet for dark matter."

Biased galaxy formation would also work if the missing mass were not cold dark matter, but neutrinos. White's computer simulations found that a neutrino-filled universe would form galaxies in much tighter clumps than we actually see. Paul Shapiro at the University of Texas in Austin says he can bypass that problem by using biased galaxy formation to create galaxies, not in the tightest knots of neutrinos, but in those less tight. Perhaps the first objects to form in the tightest knots would explode, he says, thereby heating the surrounding gas and preventing galaxies from coalescing. One problem with this idea is that the neutrino knots may produce side-effects that no one has yet seen. The other problem is that the neutrino steadfastly declines to produce a mass despite repeated careful experiments. "In fact," says Shapiro, "I'm really agnostic about neutrinos. But the sad reality is that in the long run — unless we appeal to some kind of complicated hydrodynamical processes like explosions to segregate the dark and luminous matter — cold dark matter is as likely to fail as neutrinos."

Biased galaxy formation in a universe of cold dark matter, says Peebles, "is very big now. But my bet is, it doesn't work. For one thing, unless the dark matter is moving at relativistic speeds, gravity should pull on all matter alike."

Cosmologists also worry about perceptual effects. Maybe we see patterns of clustering in those snowy peaks because our brains simply prefer to see patterns. Even Bahcall and Soneira's statistical clustering could be skewed by a perceptual effect: as the data base for their analysis, they used George Abell's catalog of rich clusters — clusters that were identified visually.

"Solving your problems by assigning qualities to an invisible substance is an old trick," says one astronomer. "It's been used since the Middle Ages!" Invisible substance or not, the dark matter is indisputably real. "If you believe in Newtonian physics," says Nick Kaiser, "you have to believe the mass is really there." "Cold dark matter isn't a bad picture for what the dominant matter is doing," says Simon White. But "we need to test it with simulations to see if it will form galaxies in a biased way." At present, computers lack the power and resolution to make such simulations feasible.

The problem of how galaxies originated simply needs new data. Except for Bahcall's correlation function for clusters, the only new observations in the last few years have confirmed older observations. Even more recently, Bruno Binggelli at the University of Basel found that the axis of the central brightest galaxy in a cluster lined up with the axis of the cluster. He also found that the aligned axes of the central galaxy and cluster pointed toward the nearest neighboring cluster. A year later, Stanislav Djorgovski at the University of California at Berkeley found that the axes of galaxies in the nearby Coma Cluster align with the axis of the cluster itself. "This effect," notes Djorgovski, "gives strong support to the adiabatic [bottom-up] picture of galaxy and cluster formation." The alignment, if real, might also result from the behavior of a parent pancake. But the observations haven't been conclusively reproduced and are reportedly beset by instrument problems. "No one disputes the work," says Simon White, "but no one believes it's due to something real."

Observations of young galaxies are badly needed, but they're not forthcoming. Any young galaxy is too dim and obscured by intervening material — in any case, astronomers aren't even sure how to look for them. "If we saw what young galaxies are like," writes Peebles, "it would settle a lot of arguments."

"Solving your problems by assigning qualities to an invisible substance is an old trick. It's been used since the Middle Ages!"

Meanwhile, alternative theories run rampant. Jeremiah Ostriker at Princeton and Lennox Cowie at the Space Telescope Science Institute suggest a way around the smoothness problem. "Maybe formation of galaxies is constrained not by fluctuations in the microwave background," says Cowie, "but by the dynamics of the primordial intergalactic gas. Maybe galaxy formation is an analog to star formation." The first things formed would have been small systems of massive stars which would soon become supernovae. Their explosions would create a shock wave, sweeping matter into a shell — a larger version of present-day supernova remnants. As the material cooled, it would condense and become gravitationally unstable. This instability might form galaxies. The stars in these galaxies would eventually explode, creating another shock wave and repeating the cycle. "We don't know one way or the other whether it's true," says Cowie. "We have no observational tools to check whether it happened, no constraints at all. But I'll bet that the problem of galaxy formation will be solved by this sort of thinking, and not the cosmological sort."

On the other hand, a particularly striking theory says that galaxies are formed by defects in the topology of space-time, called strings. Strings have only one dimension, are either infinitely long or looped back on themselves, and have masses as large as superclusters. Yakov Zel'dovich in 1980 and Alexander Vilenkin of Tufts University in 1981 suggested that the gravitational effects of strings would attract matter, which could then collect into galaxies. In 1984, Nick Kaiser and Albert Stebbins at Berkeley proposed that moving strings would leave a "wake" in the microwave background. Others say the strings might create detectable gravitational waves.

"The general reader, having survived to this point, may understandably be feeling that speculation is becoming too unbridled," wrote Dennis Sciama of Oxford in a recent review of issues in cosmology. "My own view is that the missing mass problem is here to stay."

"The field is in a state of flux," says Simon White. "Nothing definite, no conclusions, only some progress."

Ann K. Finkbeiner is a freelance science writer with a strong interest in cosmology. Her last article for ASTRONOMY was "Fossils of Something Interesting" in the November 1984 issue.

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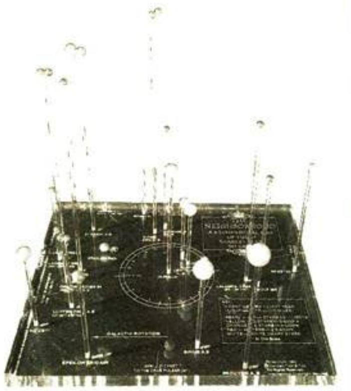

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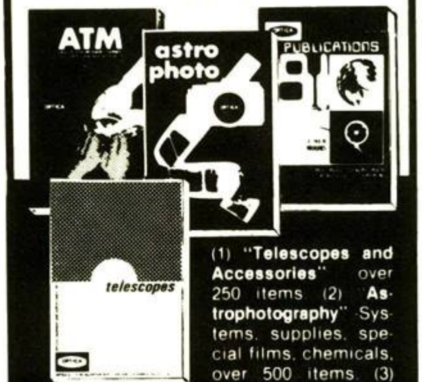

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14 Special Stars

Gazer's Gazette

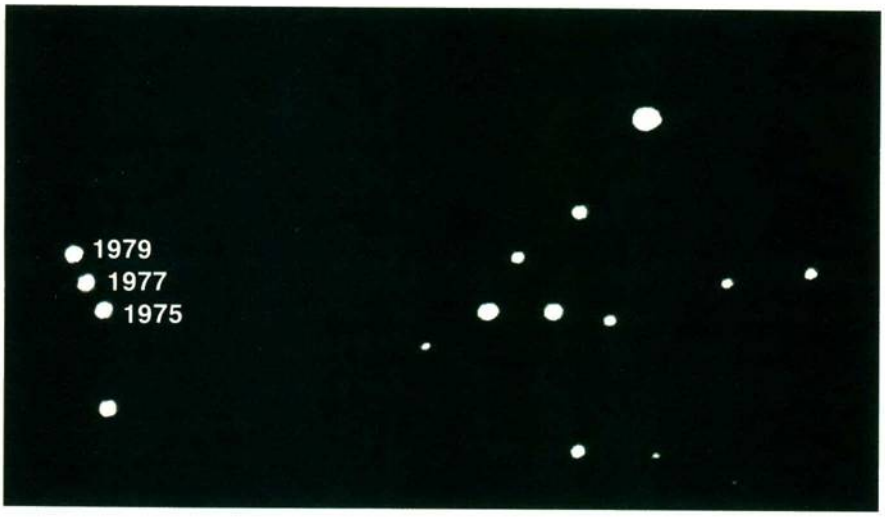
by
F. Michael Witkoski

Double, multiple, and variable stars have always been popular for backyard observers. Not only are they fun to watch from minute to minute — or even from decade to decade — they have provided valuable clues toward our present understanding of the nature of stars. The motions of double stars provide the most reliable measure of stellar masses, while the gentle flickering of variable stars also reveals much about their inner workings. Add to those classics some of the "special" stars that astrophysicists have discovered as truly unusual, and you've got an observing program that's both fascinating and informative. So let's get started. . . .

Barnard's Star

Tonight's sky would be familiar to the sages of antiquity, despite the confusion they might experience if transported to modern times. Although stars commonly revolve around the center of our Galaxy at velocities of tens of kilometers per second, they are so far apart that their apparent positions do not change for thousands of years.

A measure employed to accommodate our earthbound viewing is *seconds of arc*. A second of arc equals $\frac{1}{60}$ of a minute of arc, which equals $\frac{1}{60}$ of a degree of arc, which equals $\frac{1}{360}$ of a full circle around the sky. Roughly speaking, a small coin several kilometers away measures one second of arc across — a small diameter indeed! A star's motion in the sky with respect to other stars is called *proper motion*. When carefully examining photographic plates of the sky taken several years apart, astronomers found that a dim reddish star in Ophiuchus emerges with a great proper motion of 10.29 seconds of arc per year. At this rate, it moves a distance equal to our Moon's diameter once every 175 years. Had this star been brighter and a member of a constellation, its movement since the time of ancient Greece would have considerably changed a familiar pattern of stars.



A composite print made from three negatives shows the motion of Barnard's Star with respect to others in the field. Photo by John Sanford.

This star was discovered in 1916 by E.E. Barnard and fittingly carries his name. Barnard's Star owes its rapid proper motion partly to its distance of only 6.0 light-years. Also, its true motion in space, nearly 170 kilometers per second, is well above average. These two factors combine to give Barnard's Star top honors in the high proper motion category.

Barnard's Star shines at magnitude 9.5 — it is visible without difficulty in binoculars or a small telescope. At the moment, it lies about one degree northwest of the naked-eye star 66 Ophiuchi. Compare its position with those in photographs made 20 or 30 years ago and you'll see that Barnard's Star moves considerably. It is a constant reminder that nothing in the universe remains changeless.

61 Cygni

Another object with a large proper motion is 61 Cygni, a handsome pair of orange stars. The pair is visible without optical aid as a single star, thus making it the naked-eye star with the greatest proper motion — 5.22 seconds of arc per year.

While its annual movement is significant, 61 Cygni is also important historically, being the first star whose parallax was observed (by Prussian astronomer Frederich Wilhelm Bessel in 1838). Parallax is the change in apparent direction of a star every six months resulting from the Earth's revolution around the Sun. The nearer the star to us, the greater the parallax. Thus, 61 Cygni is the first star (other than the Sun) whose distance was determined.

61 Cygni's parallax is 0.3 second of arc, which corresponds to a distance of 11 light-years and makes it fourth closest of the naked-eye stars. The measurement is difficult and requires great care, so Bessel's

accomplishment was a true milestone.

Its handsome duplicity, rapid proper motion, and historical acclaim make 61 Cygni a noteworthy star. It lies about 8° southeast of Deneb, the brightest star in Cygnus, and at a fairly high declination above the celestial equator. The star is accessible most of the year for northern latitude observers.

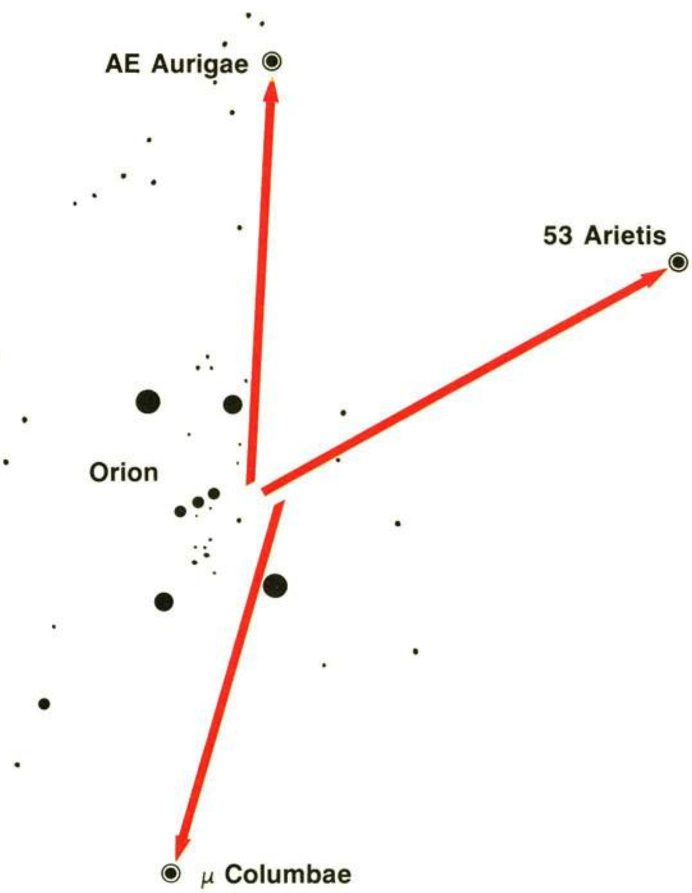
As with Barnard's Star, comparisons of 61 Cygni's present position with that shown in photographs several years old reveal its proper motion.

The Runaways: 53 Arietis, AE Aurigae, and Mu Columbae

In the constellations Aries, Auriga, and Columba lie three stars just bright enough to see without a telescope which are related in a curious way. They are 53 Arietis, AE Aurigae, and Mu (μ) Columbae. Their proper motion suggests they were once part of the Orion Association, a vast stellar birthplace. Although they move only about 0.03 second of arc per year — scant when compared to the motion of Barnard's Star — backtracking a few million years tells us that they arose in the same place at the same time.

Although Mu Columbae lies far below the equator, it is visible from northern latitudes during winter in its position about 26° due south of the Great Orion Nebula. Mu's two sibling stars, however, are better placed for northern observers.

In contrast to Barnard's Star and 61 Cygni, the Runaway Stars are about 1500 light-years distant. Their apparent brightness reveals that, on an absolute scale, they are very luminous stars. According to principles of stellar evolution, brighter stars burn their fuel rapidly and consequently "die" young. The lifespans of these three stars are measurable in millions of years — as compared with billions of years for Barnard's Star or our Sun. After a short life, these three stars will leave us, while dimmer and less profligate denizens of the Galaxy will endure for a much longer period.



Although you would never suspect it, AE Aurigae, 53 Arietis, and μ Columbae — three stars in widely different parts of the sky — were all born in the same place at the same time, in Orion.

Delta Herculis

Double stars are common and total the majority of stars in our Galaxy. Delta (δ) Herculis contains an exception — an optical double — two stars associated only by line-of-sight. Since the pair is not gravitationally bound, the components move independently — only coincidence has "brought them together" for earthbound observers. Their closest approach was nine seconds of arc in 1960. Now separating at a rate of one second of arc every few years, the pair will no longer appear to be a close double several centuries from now. Delta Herculis is only temporarily a special star.

Delta Cephei

If we travel to Cepheus, we encounter another double star, but one famous for another reason. It is Delta (δ) Cephei, the brightest member of an important class of variable stars called Cepheids. Its magnitude ranges from 3.6 to 4.3 during a cycle requiring exactly 5.37 days. Delta Cephei pulsates very regularly, enabling early 20th century astronomers to calibrate the extent of our Galaxy — a critical step toward our present understanding of the universe.

Lying 41 seconds of arc from the major component is the nicely complementary, but overshadowed, companion. Any telescope will reveal the secondary and, if only for a moment, its beauty makes us forget about the importance of the primary star.

Mu Cephei and S Cephei

Two more unusual stars lie in Cepheus: Mu (μ) Cephei (also known as "Herschel's Garnet Star"), located 12° due west of Delta Cephei, and S Cephei, positioned only 12° from the north celestial pole.

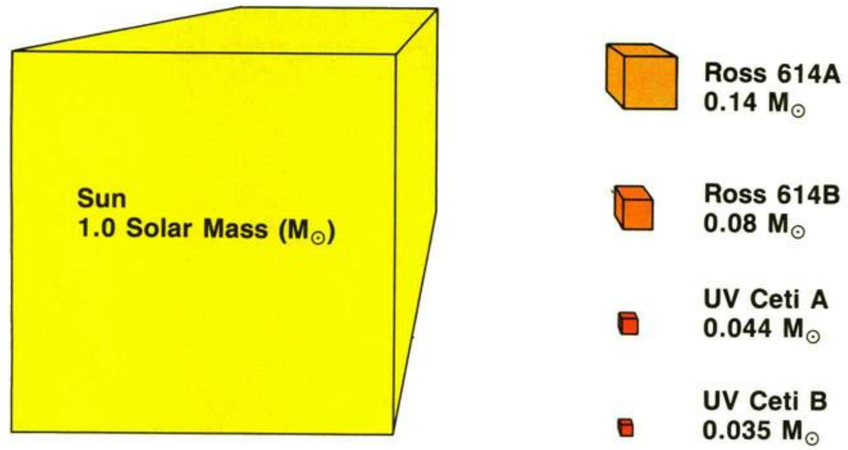
Each is among the reddest stars known. Mu is more intensely red than any other naked-eye star, although a telescope best shows its color, while S is probably the reddest star viewable through a backyard telescope.

As do many red stars, Mu and S vary in brightness. Mu ranges from magnitudes 3.7 to 5.0, while S ranges from 7.5 to about 12. Betelgeuse and Antares, both among the brightest naked-eye stars, are also ruddy, but compared with our two stars in Cepheus their intensities seem diluted. The colors of these stars can be compared to cranberry juice: If we assume S's intensity is a pure juice solution, Mu's would equal a partially watered-down mixture, while Betelgeuse's and Antares' would be mostly water with just a touch of juice.

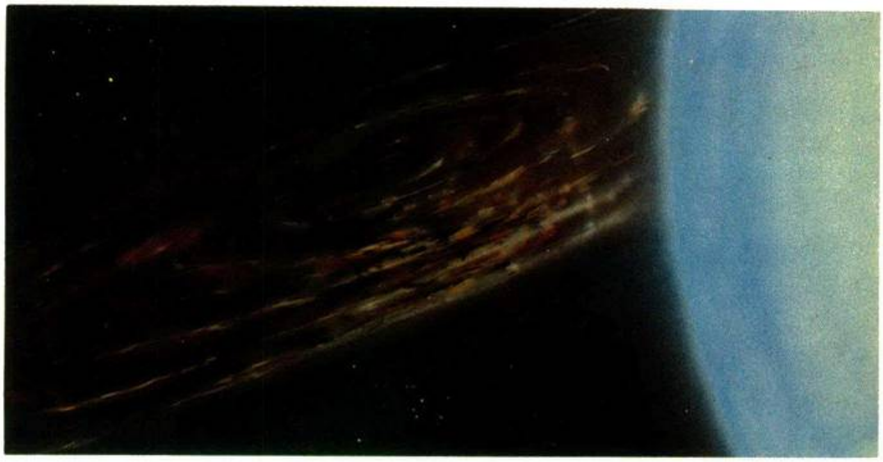
UV Ceti and Ross 614

Stars, like plants and animals, can be gigantic or minuscule. One of the smallest known stars is an invisible third companion to the 61 Cygni system. The star's existence is betrayed only by the orbital irregularities of its two brighter components; its mass is thought to be a bit less than 1% of the Sun's. A smaller body would be unable to generate the gravitational energy in its core necessary to maintain thermonuclear reactions, the power source of all stars. Jupiter, with a mass equaling ⅒ of our Sun's, is a prime example of a *"star that failed."*

In the constellation Cetus lies an unusual telescopic pair, UV Ceti, whose combined mass equals about 8% of the



Two systems containing some of the least massive stars known are Ross 614 in Monoceros and UV Ceti in Cetus. Taken together UV Ceti's two components hold less than 10% of the Sun's mass!



The star Epsilon Aurigae contains a dark eclipsing component that passes in front of a luminous star once every 27 years. Painting by Thomas L. Hunt.

Sun's. Both stars shine at magnitude 12, although the brighter component is variable and subject to sudden and irregular flare-ups every several hours. Currently, the stars are about seven seconds of arc apart, but their widening orbit will lead them to a 10-second separation within the next few decades. Through a 6-inch telescope, they should be visible on a good night. The pair is 14° due east of second-magnitude Beta (β) Ceti, one of the few bright stars in this region of the sky.

In Monoceros lies Ross 614, another low-mass pair. The components' magnitudes are 11.1 and 14.8, and their masses are 14% and 8% that of the Sun's — greater than those of UV Ceti, but still among the lowest known. The separation, unfortunately, is so small that an amateur-sized telescope will not split the pair. In fact, the 5-meter telescope at Palomar Mountain was the first to accomplish this feat.

Plaskett's Star

At the opposite end of the stellar mass scale, a star 100 or more times larger than the Sun would be unstable. However, some stars near this range have been discovered. Staying in Monoceros, we find the most massive pair of stars known. This binary, called Plaskett's Star, consists of components 40 and 60 times the mass of our Sun.

At sixth-magnitude, the pair is barely visible to the naked eye but an easy target with the most modest telescopes. The components, though, are closer together than the Earth and Sun, so your telescope will show only a single star. A spectroscope is necessary to determine the star's duplicity. To locate Plaskett's Star, look about 2° northeast of the famous Rosette Nebula.

Epsilon Aurigae

Located 3° southwest of the bright star Capella is a naked-eye binary, only one of whose components is visible. It is 3.0 magnitude Epsilon (ε) Aurigae. The dimmer member passes in front, eclipsing the primary every 27 years. The last eclipse ended June 25, 1984 and the star is now back to near maximum light. At its dimmest, the system falls to magnitude 3.8.

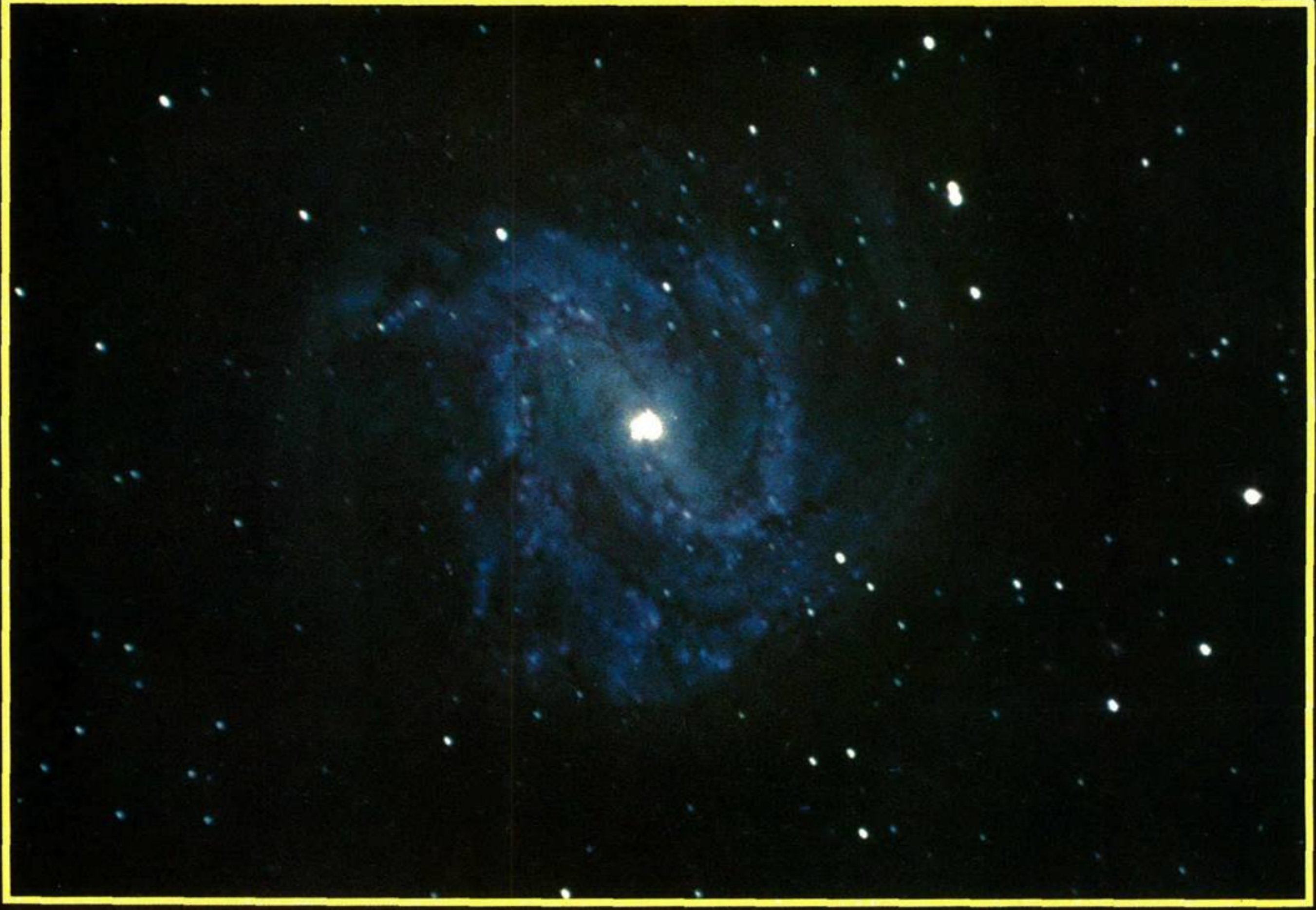
The length of Epsilon's eclipse is truly unusual — nearly two years. The most famous eclipsing binary is Algol in Perseus with a period of 2.87 days and an eclipse lasting about 10 hours. Zeta (ζ) Aurigae, 3° due south of Epsilon, is also an eclipsing binary with a period of 32 months and an eclipse length of 5½ weeks. The disparity between these more-or-less typical eclipse intervals and Epsilon's longer cycle is puzzling to astronomers. Only a star larger than any known or an immense accumulation of dust and gas could account for the extremely long eclipse. Since its first recorded eclipse in 1821, knowledge of the Epsilon Aurigae system has grown, although the mystery is far from solved.

T Tauri

For our final visit, we'll stop in Taurus. About 4° northwest of first-magnitude Aldebaran is T Tauri, a variable star associated with the dim variable nebula NGC-1555, also known as "Hind's Variable Nebula." A bit difficult for binoculars, but generally accessible to a medium-sized telescope, T Tauri ranges between magnitude 9 and 13. It is the prototype of an entire class of stars thought to be in the process of forming. In front of our very eyes, we can observe a star which is only beginning its journey through life. Since stellar lifetimes are so long, we rarely get to see a star being born or dying. With T Tauri, we come close.

We've surveyed some special and interesting stars. Whether large or small, single or double, rapidly moving through the abyss of space and time or uniquely aligned, our Galaxy's stars offer an alternative to the sometimes over-observed "showpiece objects." Best of all, this handful of specimens represents only a sample of the vast treasures awaiting us among the stars.

F. Michael Witkoski is an avid deep-sky observer and a frequent contributor to AstroMedia's DEEP SKY magazine. He is co-author of a deep-sky observing book to be published by Enslow in 1985. His last article for ASTRONOMY was "Searching for Supernovae" in the April 1982 issue.



Above: M-83, the brightest galaxy in Hydra, appears as a large circular halo of nebulosity around a bright core. Under dark skies, backyard telescopes show its spiral shape and patches of dust within the arms. Photo by Jack B. Marling. Below: The colliding galaxies NGC-4038 and NGC-4039 appear as a single nebulous arc in a small scope. Photo by Jack Newton. Below right: Although diminutive, the planetary nebula NGC-7662 is bright enough to withstand high magnification which reveals its inner detail. Photo by Joe Liddell. Bottom right: Globular cluster M-68 appears as a fuzzy ball of stars in small telescopes, requiring high power to resolve its edges. Photo by Martin C. Germano.

Corvus

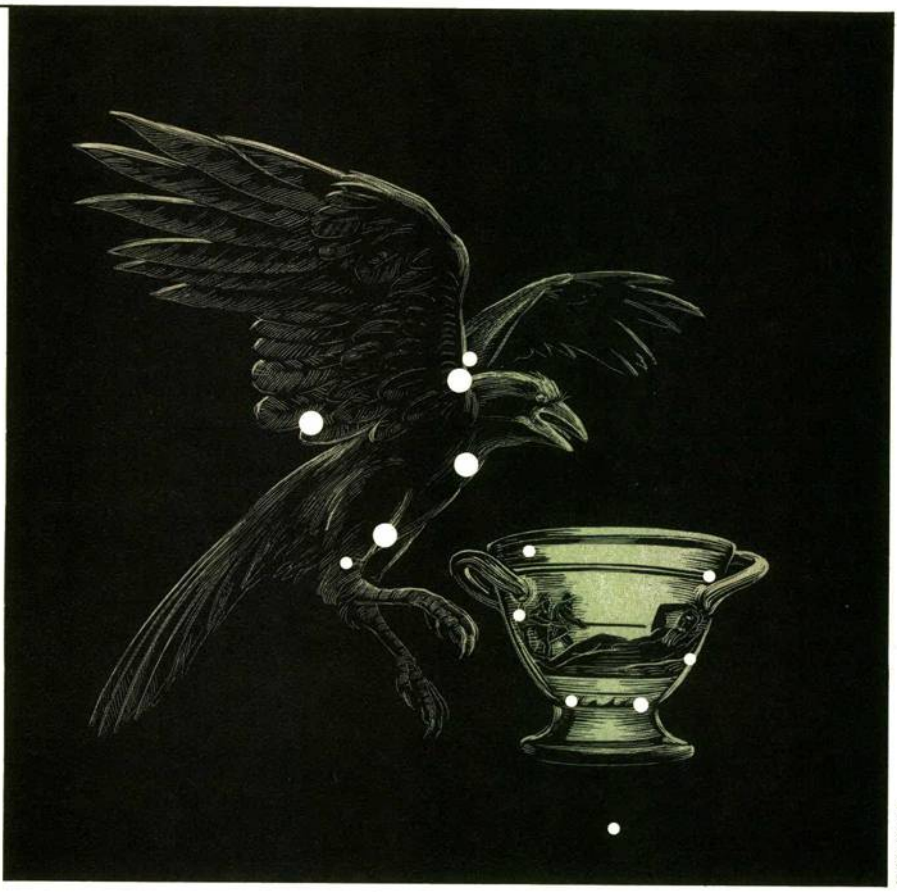
Crv
Corvi

Crater

Crt
Crateris

Eastern Hydra

Hya
Hydrae



Keith Ward

The region of sky containing Corvus, Crater, and Eastern Hydra — southwest of the great Virgo cloud of galaxies and far east of the winter Milky Way — appears barren. However, it contains many small galaxies visible in backyard telescopes and a handful of other sights, including a globular cluster, a planetary nebula, and several unusual variable stars.

Corvus' most unusual deep-sky object is the pair of interacting galaxies **NGC-4038** and **NGC-4039**. These galaxies lie some 12 megaparsecs away and shine with the combined light of an 11th magnitude star. Together, NGC-4038 and NGC-4039 measure 2.5′ x 2.5′ across. Their fuzzy, lopsided shapes — one a distorted spiral, the other a peculiar eruptive galaxy — are clearly visible in a good 8-inch telescope on a dark night. A larger telescope reveals mottled areas of detail across the galaxies' surfaces, resembling a backward question mark. These objects undoubtedly comprise one of the easiest-to-observe pairs of physically-connected galaxies.

One of the nicest planetary nebulae in the spring sky is **NGC-4361**, a magnitude 10.5 bright blue disk measuring 80″ across. When viewed with small telescopes, NGC-4361 appears as a fuzzy "star" at low power. A good 8-inch telescope at high power, however, reveals the nebula's faint outer halo which envelopes an inner bright disk. The central star shines at 13th magnitude and is rather difficult to spot, but a 10-inch or larger telescope will reveal it shining through the fluorescing ball of gas.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Delta (δ) **Corvi**, also known as Algorab, is a third-magnitude double star suitable for viewing with any size telescope. Discovered by John Herschel and James South in 1823, Algorab consists of a magnitude 3.0 primary with a magnitude 8.4 secondary 24.2″ away in position angle 214°. (The p.a. and distance have remained fixed for the last 160 years.) The primary is a spectral type B9 main sequence star, whereas the secondary is a dwarf K2-type star. Their colors are often described as yellowish and pale lilac, or simply white and orange. This system lies some 40 parsecs away, which means that the primary star shines with the luminosity of 75 Suns. In spite of the primary's brilliance, this double star is easily visible in virtually any telescope because of the secondary's considerable distance.

The pattern of stars known as Crater is somewhat ill-defined, but worth seeking out because of three galaxies which reside within its boundary. **NGC-3511** is a 12th magnitude Sc-type spiral with a bright nucleus surrounded by faint haze. A 6-inch telescope shows it as a tiny core — perhaps one arc-minute across — with a larger faint halo of nebulosity spanning perhaps 3′ across. **NGC-3672** is an Sb-type spiral, nearly as bright though somewhat smaller than NGC-3511. Observatory photos show that NGC-3672 is a highly-inclined multiple-arm spiral with numerous intertwining dust patches. But this detail is impossible to spot visually: 10-inch scopes show only a 1′ diameter bright nucleus and a smooth halo of greyish-green nebulosity. The Sc-type spiral **NGC-3887** is brighter and rounder than its neighbors, shining at magnitude 11.6 and measuring 2.6′ x 2.0′ across. A 6-inch telescope shows it as a bright, round, featureless spot.

The sprawling eastern half of the constellation Hydra contains a variety of celestial targets. Among its galaxies is **Messier 83** (NGC-5236), the finest face-on Sc-type spiral in the sky. With a combined magnitude of 8, this magnificent object is visible in binoculars as a bright nebulous disk, sharply brighter toward its center and spanning one-third the Moon's diameter. In telescopes, M-83 really shows itself: a 6-incher at high power reveals a condensed, brilliant nucleus within a weakly bar-shaped outer envelope of low surface brightness nebulosity. In between the faint spiral-structured arms are dark patches blocking the starlight, which represent huge areas of dust in the galaxy's disk.

M-83 was discovered by Nicholas Louis de Lacaille in 1752. The distance to M-83 is about 4.5 megaparsecs, making it one of the closest spiral galaxies outside our Local Group — which includes M-31, M-33, NGC-6822, and the Milky Way. A total of five supernovae have occurred within M-83 during the last 60 years, one in 1923, 1950, 1957, 1968, and 1983. This unusually high rate of producing supernovae makes M-83 a suitable target for backyard supernova hunters. Next time you're out observing M-83, take along a photo showing stars around the galaxy. If you see a star that doesn't appear on the photo, you may have made a discovery!

Three other notable galaxies are tucked away in eastern Hydra — **NGC-3109**, **NGC-3145**, and **NGC-3621**. NGC-3109 is a patchy irregular galaxy with low surface brightness. Its large dimensions of 11.0′ x 2.0′ and bright magnitude of 11 belie a tricky object, since the light is so widespread. Use a low-power ocular under dark skies, if possible; with a 6-inch scope, this will show a long, thin spike of faint nebulosity. A 10-inch telescope reveals a mottled, uneven texture along the galaxy's surface along with several faint stars in and around the nebulosity. NGC-3145 is a more typical object — a magnitude 12.5 barred spiral covering 2.4′ x 1.0′. A 10-inch scope displays it as a small, oval core enveloped in a very faint haze. A 17.5-inch telescope's view brightens the nebulosity and shows it to be mottled, but does not expose much more detail. NGC-3621, an Sc- or Sd-type spiral, measures 5.0′ x 2.0′ and shines with the light of a magnitude 10.6 star. A 6-inch telescope shows this galaxy as a large and bright oval nebulosity containing a condensed nucleus.

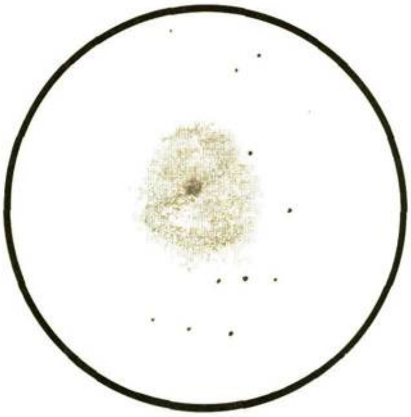
Eastern Hydra contains two fine variable stars — **R Hydrae** and **V Hydrae**. R Hya is a Mira-type long period variable whose period of 386 days carries the star between magnitudes 4 and 10. Although it is visible to the naked eye for only several weeks during each cycle, this star can be followed with binoculars or a small telescope. V Hyd is a semi-regular variable with a period of 533 days. It varies between magnitudes 6.5 and fainter than 12, so you'll need a 6-inch scope to follow its complete cycle.

Another M-object in Hydra is **Messier 68** (NGC-4590), a bright, medium-sized globular cluster of stars. Although it isn't as spectacular as M-13 in Hercules or perhaps M-22 in Sagittarius, M-68 measures a full 9′ across and glows at magnitude 8; it is obviously nonstellar even in binoculars. Under dark skies, a 4-inch scope at high power shows M-68 as a large, fuzzy ball of unresolved light. An 8-inch telescope at high power begins to resolve M-68's edges, showing it to be a cluster of stars. **NGC-5694** is an 11th magnitude globular measuring only 2′ across — it is one of the most distant globulars and impossible to resolve with backyard telescopes.

Tiny, yet often observed, planetary nebula **NGC-3242** has much to offer for small telescope viewers. It shines at 9th magnitude, measures 40″ across, and contains an obvious 11th magnitude central star. Binoculars show NGC-3242 as a bluish "star," but small telescopes at medium power display its disk and may even reveal the central star as a tiny dot inside the nebula. Large telescopes — in the 10-inch to 20-inch range — show that NGC-3242 is composed of a bright central star, a bright inner disk, and a fainter outer halo of greenish-blue nebulosity.

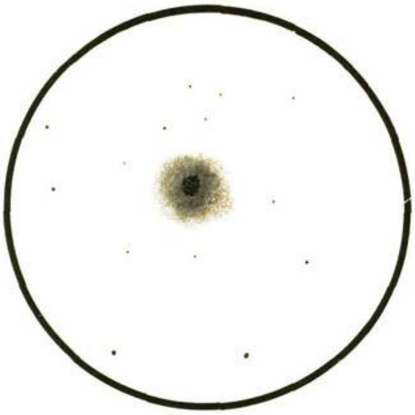
M-83

8-inch f/10 SCT
50x



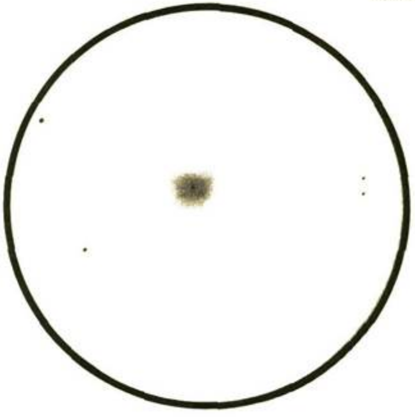
M-68

8-inch f/10 SCT
100x



NGC-3242

17.5-inch f/4.5
reflector
100x

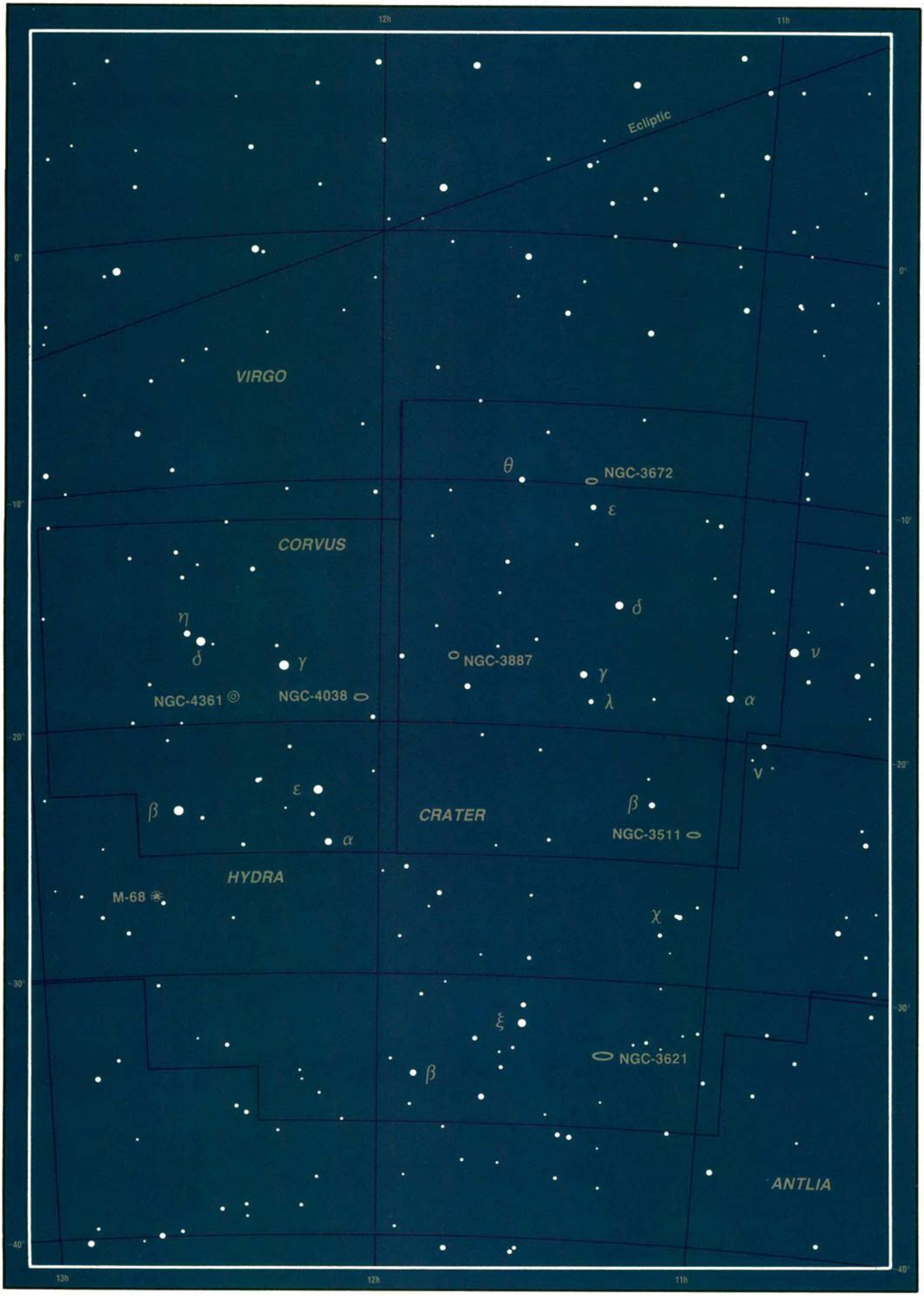


Sketches by David J. Eicher

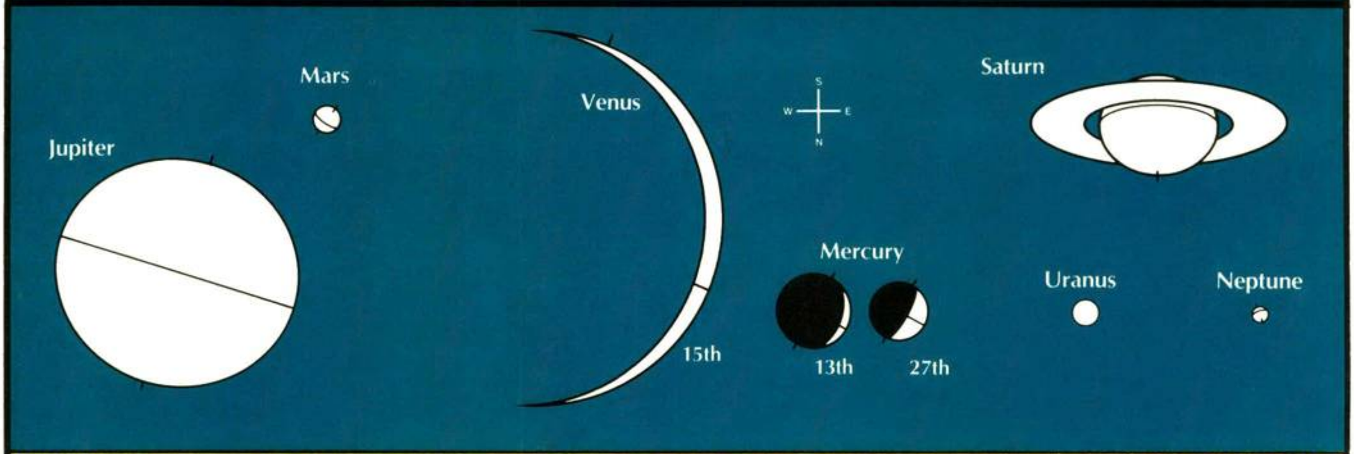
Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-3109		#	10h 03.1m	−26°10′	11.2	11.0′x2.0′	I
NGC-3145		§B	10h 10.1m	−12°25′	12.5	2.4′x1.0′	SBb
NGC-3242		■	10h 24.8m	−18°38′	8.9	40″	
V Hya		SRV	10h 51.6m	−21°15′	6.5↔12...	533d	
NGC-3511		§	11h 03.2m	−23°06′	11.9	4.2′x1.5′	Sc
NGC-3621		§	11h 18.3m	−32°48′	10.6	5.0′x2.0′	Sc/Sd
NGC-3672		§	11h 25.0m	− 9°48′	11.8	3.5′x1.4′	Sb
NGC-3887		§	11h 47.1m	−16°52′	11.6	2.8′x2.0′	Sc
NGC-4038/9		#	12h 01.9m	−18°52′	11.0	2.5′x2.5′	S?pec
NGC-4361		■	12h 24.5m	−18°46′	10.5	80″	
δ Crv		★^{2}	12h 29.9m	−16°31′	3.0,8.5	24.2″	
NGC-4590	M-68	●	12h 39.5m	−23°16′	8.0	9.0′	
R Hya		LPV	13h 29.7m	−23°16′	4.0↔10.0	386d	
NGC-5236	M-83	§	13h 37.1m	−29°52′	8.0	10.0′x8.0′	Sc
NGC-5694		●	14h 39.6m	−21°32′	11.0	2′	

H = Hubble classification type for galaxies

★^{2}	*Double Star*
LPV	*Long Period Variable*
SRV	*Semi-Regular Variable*
●	*Globular Cluster*
■	*Planetary Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*
#	*Peculiar/Irregular Galaxy*

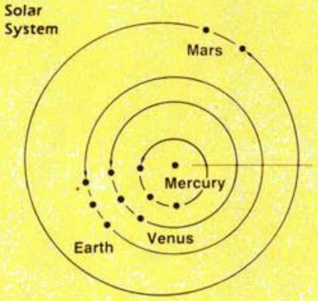

12h
11h
Ecliptic
0°
0°
VIRGO
θ
NGC-3672
ε
-10°
-10°
CORVUS
δ
η
δ
γ
NGC-3887
γ
ν
NGC-4361
NGC-4038
λ
α
-20°
-20°
V
ε
β
β
CRATER
NGC-3511
α
HYDRA
M-68
χ
-30°
-30°
ξ
NGC-3621
β
ANTLIA
-40°
-40°
13h
12h
11h

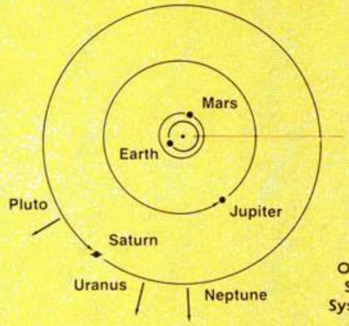
Planetary Data April 1985


Mars
Jupiter
Venus
15th
S
W
E
N
Saturn
Mercury
13th
27th
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	32.1′	—	1.00	—	—	11°13.3′	0h 42.0m	4°31.0′
		15	−26.7	31.9′	—	1.00	—	—	24°58.8′	1h 33.3m	9°44.6′
		30	−26.7	31.8′	—	1.01	—	—	39°36.5′	2h 29.6m	14°45.3′
Mercury	☿	1	4.4	11.0″	2%	0.61	0.39	184°08.6′	15°53.0′	0h 53.9m	9°10.5′
		15	2.0	10.8″	14%	0.62	0.45	230°08.6′	7°09.0′	0h 26.5m	2°40.4′
		30	0.6	8.3″	41%	0.81	0.46	271°51.7′	13°07.2′	0h 52.6m	2°38.1′
Venus	♀	1	−4.1	58.8″	1%	0.28	0.72	189°23.4′	15°57.4′	0h 46.8m	13°41.3′
		15	−4.2	55.3″	5%	0.30	0.72	211°56.5′	8°13.0′	0h 21.1m	8°31.0′
		30	−4.5	44.7″	18%	0.37	0.72	235°56.7′	7°07.3′	0h 20.9m	4°47.1′
Mars	♂	15	1.5	4.0″	98%	2.34	1.52	69°31.4′	52°15.0′	3h 18.9m	18°43.7′
Jupiter	♃	15	−2.2	36.9″	99%	5.34	5.12	302°24.0′	313°20.4′	21h 03.8m	−17°16.3′
Saturn	♄	15	0.2	18.3″	100%	9.06	9.93	233°52.9′	237°09.4′	15h 41.7m	−17°14.3′
Uranus	⛢	15	5.5	3.8″	100%	18.45	19.07	255°21.6′	257°51.9′	17h 07.7m	−22°55.0′
Neptune	♆	15	7.9	2.2″	100%	29.87	30.26	271°49.4′	273°43.4′	18h 16.4m	−22°14.4′
Pluto	♇	15	13.7	0.1″	100%	28.82	29.77	213°18.0′	213°48.2′	14h 29.4m	3°30.9′

Inner Solar System

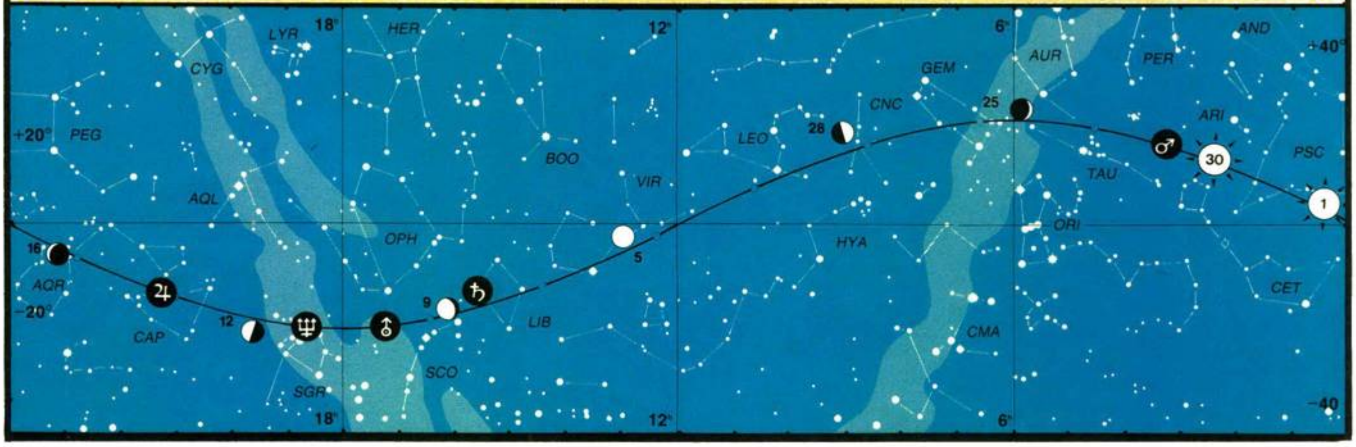

Mars
Mercury
Venus
Earth


Mars
Earth
Jupiter
Pluto
Saturn
Uranus
Neptune

Outer Solar System

Moon Data

Full Moon	April 5 at 11h32m
Last Quarter	April 12 at 4h41m
New Moon	April 20 at 5h22m
First Quarter	April 28 at 4h25m
Full Moon	May 4 at 19h53m
Last Quarter	May 11 at 17h34m
Perigee: April 5 at 18h28m	356,973 km.
Apogee: April 19 at 17h23m	406,539 km.


LYR
18°
HER
12°
6°
AND
+40°
CYG
GEM
AUR
PER
+20°
PEG
CNC
25
ARI
LEO
28
BOO
TAU
30
PSC
AQL
VIR
1
ORI
16
OPH
5
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9
CET
12
CAP
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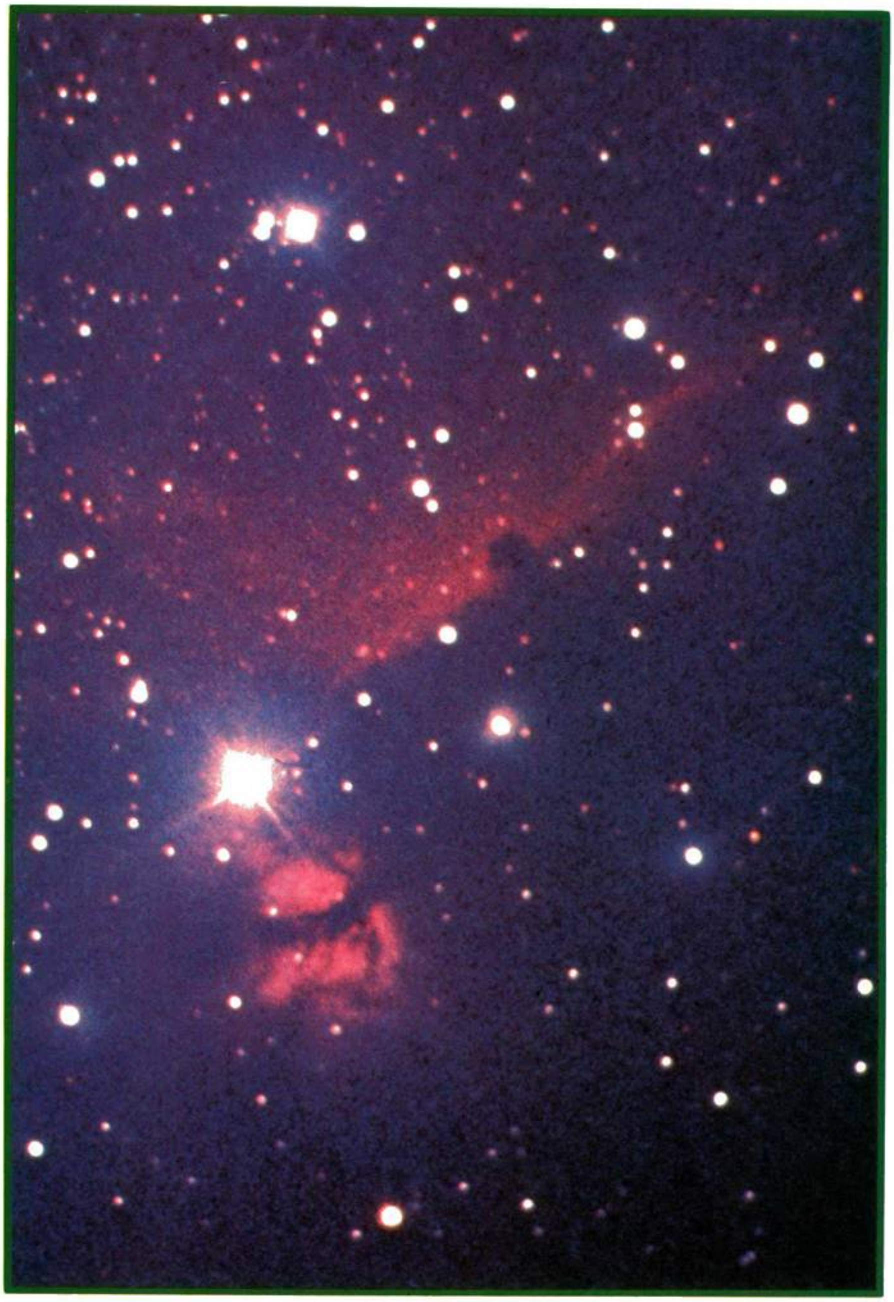
SCO
SGR
18°
12°
6°
−40



The Horsehead Nebula is one of Orion's best — and most elusive — deep-sky sights. John Kerns used a 4¼-inch f/5 scope, hypered Fujichrome 400 film, and a half-hour exposure. His original slide was then duped and enlarged.

Mercury

Mercury's brief evening apparition last month was relatively favorable; unfortunately, the morning one during April and May will be the year's worst. Greatest elongation is on May 1st, but you won't be able to see the planet until the latter half of April. If you're keen to spot this elusive object with your telescope, wait for its evening apparition in June and July.

Venus

Venus passes out of the evening sky, zips between the Earth and Sun, and rises into the morning sky on April 3rd. Repeating what your scope showed in the evening sky in March — but in reverse order — Venus will undergo rapid and dramatic phase changes during the weeks to come. Try to sketch or photograph it each morning — this will enhance the fun of watching and preserve your memories of the event.

Mars

Mars is a second-magnitude reddish dot of light in the evening sky, but its 4.0" disk offers little for telescopic observers.

Asteroids

1 Ceres (magnitude 8.5) is moving eastward in northern Taurus, about 5° north of Aldebaran. Its positions:

10th: 4h 13m 39s, 21° 10.6′
20th: 4h 29m 45s, 22° 08.4′

Ceres sets around 11 p.m. local daylight time on the 15th.

2 Pallas (9.6) is in conjunction with the Sun on April 5th; it will be out of view all month.

3 Juno (9.7) lies in western Virgo, where it is moving northwestward. Its positions:

10th: 12h 15m 43s, 4° 36.8′
20th: 12h 09m 27s, 5° 40.8′

Juno sets about 5:30 a.m. local daylight time at mid-month.

4 Vesta (6.1) is at opposition on April 18th; it lies in eastern Virgo, about 10° northeast of Spica. Its positions:

10th: 14h 13m 22s, −0° 02.1′
20th: 14h 04m 23s, 0° 47.3′

Vesta transits around 1:30 a.m. local daylight time on the 15th.

Jupiter

Try observing the Galilean moons as they disappear into Jupiter's shadow — or emerge from it. Io, the innermost moon, has many such events, but those timed well for North American observers are its disappearances on the 7th (9h28m UT), 14th (11h22m), 21st (13h16m), and 30th (9h38m). Europa disappears on the 17th (9h56m) and 24th (12h31m). Both Io and Europa come out of the shadow when behind the planet.

Ganymede and Callisto orbit far enough from Jupiter that you can see them emerge from the shadow cone before they vanish behind the massive bulk of Jupiter. Unfortunately, these moons have no well-timed events this month: the best — for East Coast and Maritime observers — are Callisto on the 9th (disappears 5h53m, emerges 10h23m) and Ganymede on the 25th (d = 4h45m, e = 8h19m).

Saturn

Saturn's rings are tipped 23⅓° toward us; they make a lovely sight in almost any telescope. (Binoculars usually show Saturn's "dot" as non-stellar, but that's about all.) Use 50x on a telescope, however, and the planet's tiny perfect image comes into full view. Know anyone who needs a good hobby? Show 'em Saturn!

Uranus

Use the finder map in the January issue (page 83) to locate the region in Ophiuchus that contains Uranus. Put a low-power eyepiece in your scope and sweep the area slowly. Look for a distinct disk that appears bright greenish-blue.

Neptune

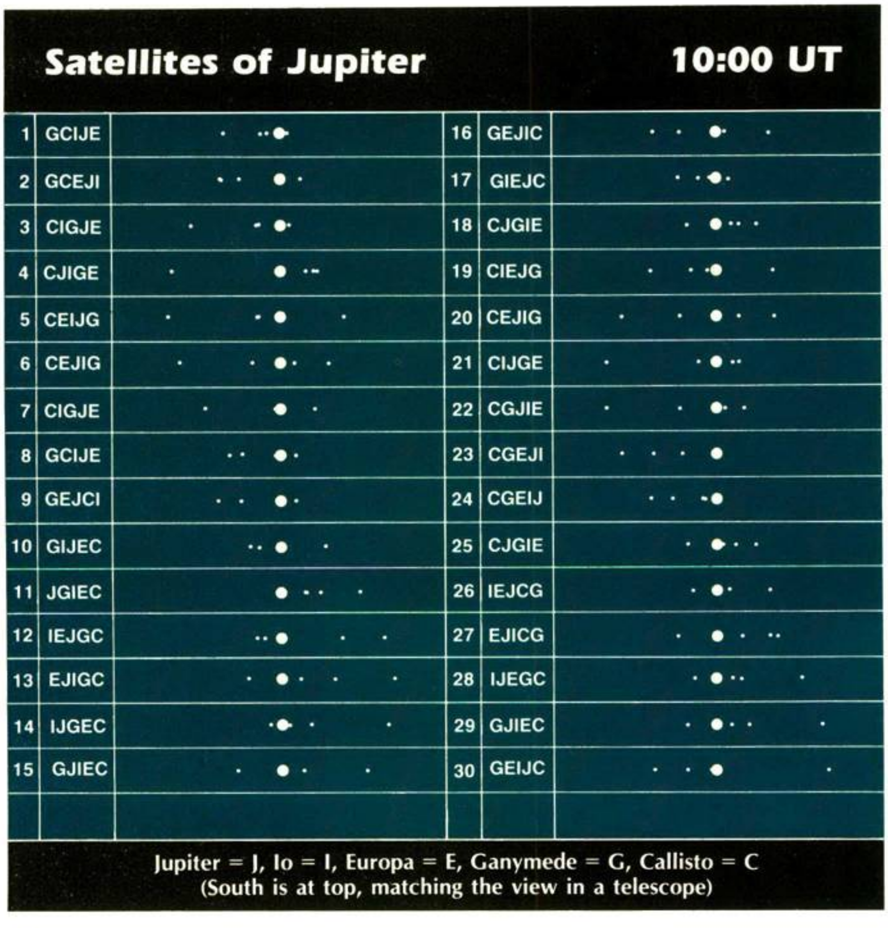
In Sagittarius, Neptune is about the same size as Uranus, but lies more than 1.5 light-hours farther away. Its magnitude 8 disk is 2.2" across (for a finder chart, see the January issue).

Pluto

Pluto reaches opposition on April 23rd in Virgo (see finder chart, January issue). At magnitude 13.7, Pluto shows no appreciable disk and most observers need at least an 8-inch scope to spot it.

In late April and early May, Pluto will pass near two stars. The first is 7.9 magnitude SAO 120474 (α = 14h 27m 46.6s, δ = +3° 37′ 16″, 2000.0). Pluto passes 1′ 37″ north of this star on April 31st. The star is the fainter of the two above the galaxy NGC-5638 on plate 18

Right: Seen nearly edge-on is the spiral galaxy NGC-3190 (center) part of a small group of galaxies lying between Gamma (γ) and Zeta (ζ) Leonis. Gary Hug's photo — April's Best Astro-Photo winner — was taken in 40 minutes with a 17½-inch f/4.5 scope on Fujichrome 400 film. The film was processed in C-41 chemistry and pushed half a stop. Above: Glenn Hardcastle's pretty aurora photo was taken in January 1978; no data available.



Satellites of Jupiter — 10:00 UT

1	GCIJE	16	GEJIC
2	GCEJI	17	GIEJC
3	CIGJE	18	CJGIE
4	CJIGE	19	CIEJG
5	CEIJG	20	CEJIG
6	CEJIG	21	CIJGE
7	CIGJE	22	CGJIE
8	GCIJE	23	CGEJI
9	GEJCI	24	CGEIJ
10	GIJEC	25	CJGIE
11	JGIEC	26	IEJCG
12	IEJGC	27	EJICG
13	EJIGC	28	IJEGC
14	IJGEC	29	GJIEC
15	GJIEC	30	GEIJC

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

of *Sky Atlas 2000.0*. On May 8th, Pluto passes 44″ north of 8.5 magnitude SAO 120466 (α = 14h 26m 58.4s, δ = 3° 41′ 15″, 2000.0).

Meteors

April features only one meteor shower of note — the Lyrid. Sometimes prefixed "the April" (to distinguish them from a lesser Lyrid shower that occurs in mid-June), the Lyrids are relatively fast but sparse — zenithal hourly rates hover around 15. The radiant lies near the Hercules/Lyra border and maximum this year is April 22nd, with the Moon two days old.

Comet Halley

Halley's comet passes out of Orion into Taurus late in April. The comet's positions (epoch 2000.0 coordinates) are:

10th: 4h 55m 13s, 15° 20.1′
20th: 4h 57m 31s, 15° 45.7′

On April 15th, Comet Halley will be 4.86 AUs from Earth and at magnitude 15.9.

CHALLENGER
7
CRIPPEN FABIAN HAUCK RIDE THAGARD

STS 7 Enlarged to show detail.

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MER 7

MERCURY 7
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MER 8

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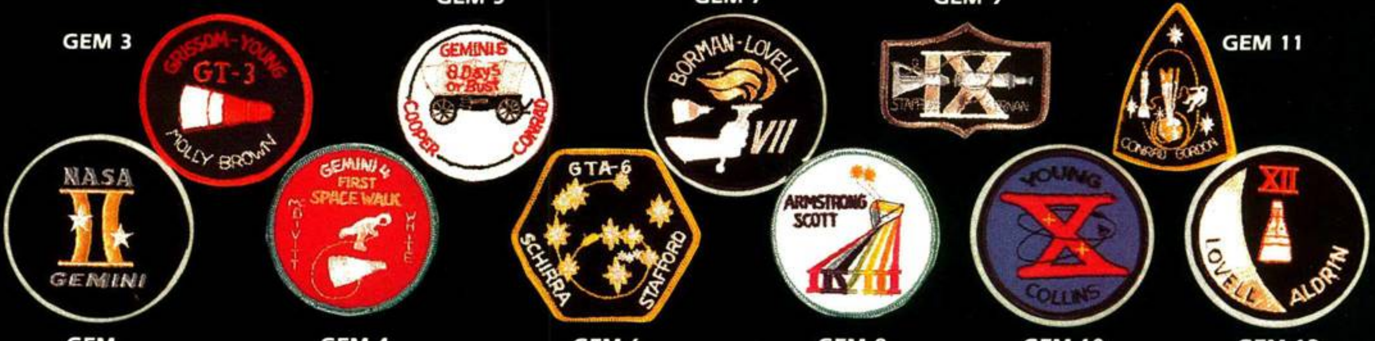
GRISSOM-YOUNG
GT-3
MOLLY BROWN
GEMINI 5
8 Days or Bust
COOPER
CONRAD
BORMAN-LOVELL
VII
STAFFORD
IX
CERNAN
CONRAD
GORDON
NASA
II
GEMINI
GEMINI 4
FIRST SPACE WALK
McDIVITT
WHITE
GTA-6
SCHIRRA
STAFFORD
ARMSTRONG
SCOTT
VIII
YOUNG
X
COLLINS
XII
LOVELL
ALDRIN

GEM 3 **GEM 5** **GEM 7** **GEM 9** **GEM 11**

GEM **GEM 4** **GEM 6** **GEM 8** **GEM 10** **GEM 12**

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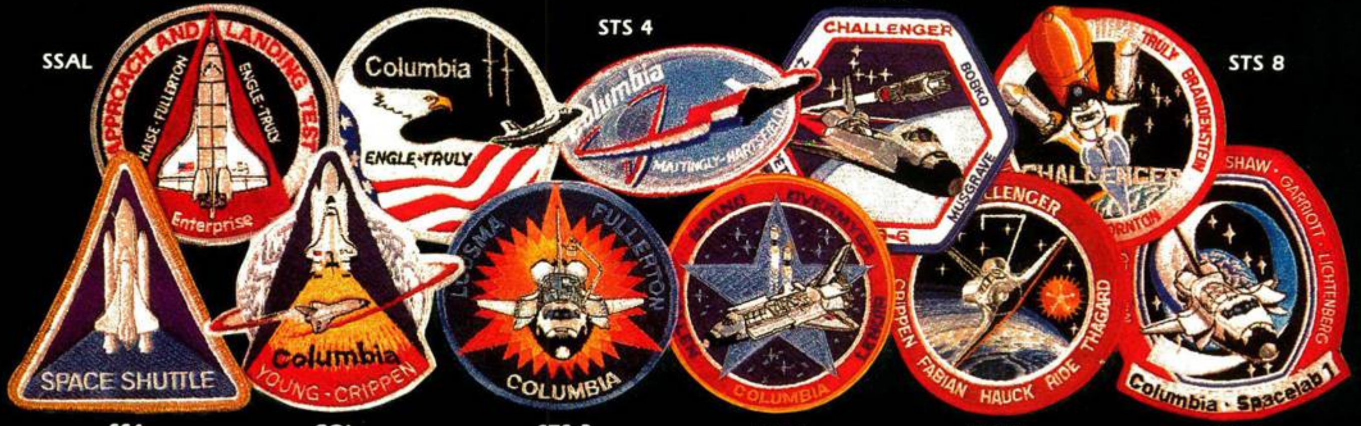
APPROACH AND LANDING TEST
HAISE · FULLERTON
ENGLE · TRUKY
Enterprise
Columbia
ENGLE · TRULY
Columbia
MATTINGLY · HARTSFIELD
CHALLENGER
BOBKO
MUSGRAVE
TRULY
BRANDENSTEIN
CHALLENGER
SPACE SHUTTLE
Columbia
YOUNG · CRIPPEN
LOUSMA
FULLERTON
COLUMBIA
BRAND
OVERMYER
LENOIR
COLUMBIA
CHALLENGER
7
CRIPPEN FABIAN HAUCK RIDE THAGARD
SHAW · GARRIOTT · LICHTENBERG
Columbia · Spacelab 1

STS 2 **STS 4** **STS 6**

SSAL **STS 8**

SS4 **COL** **STS 3** **STS 5** **STS 7** **STS 9**

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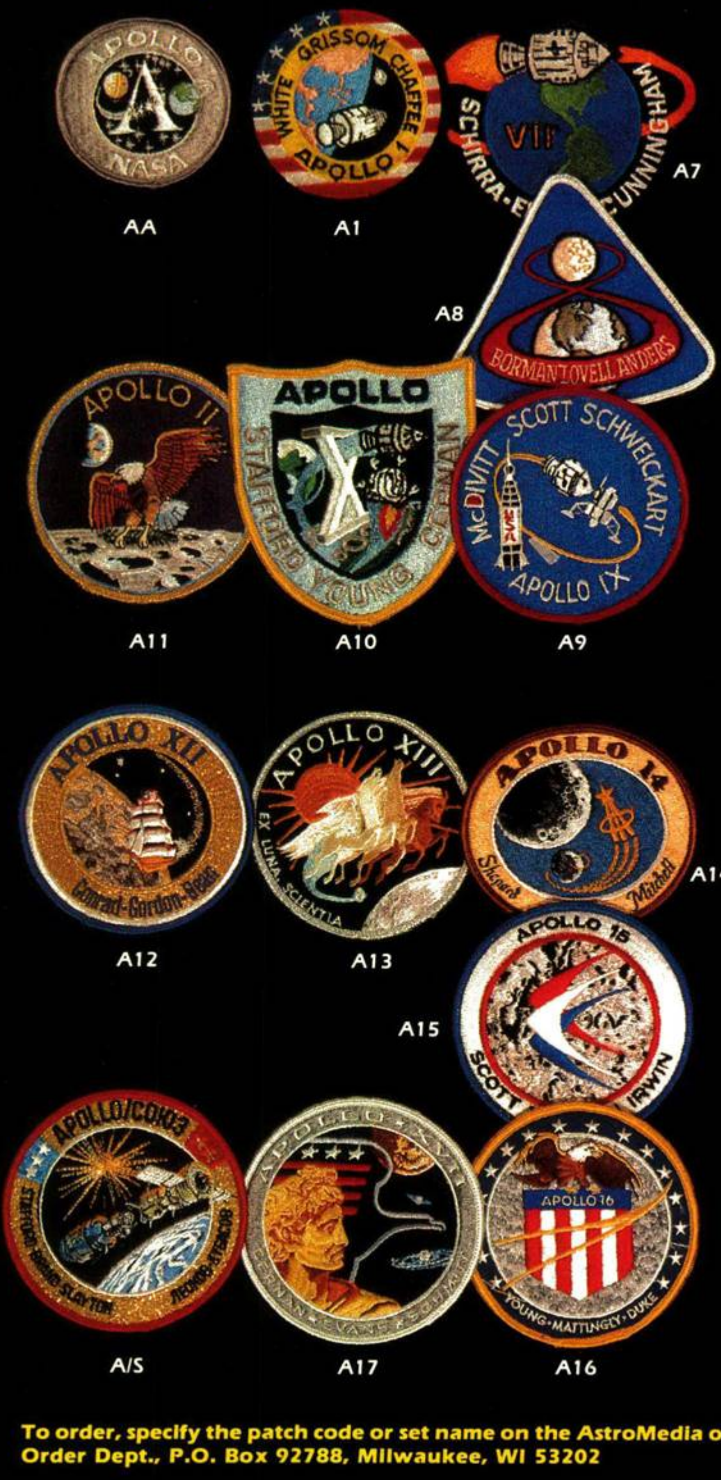
AA
A1
A7
A8
A11
A10
A9
A12
A13
A14
A15
A/S
A17
A16

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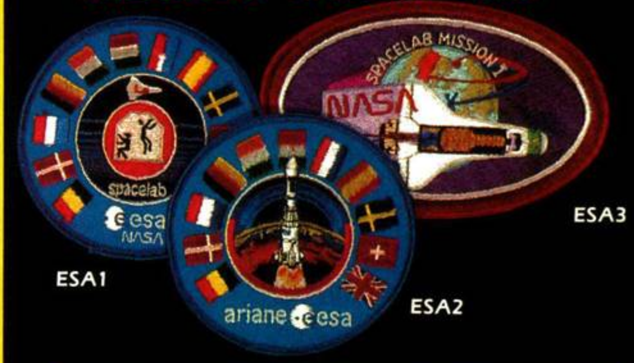
ESA1
ESA2
ESA3

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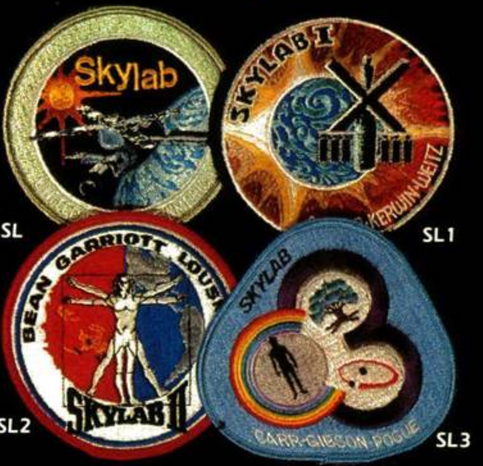
SL
SL1
SL2
SL3

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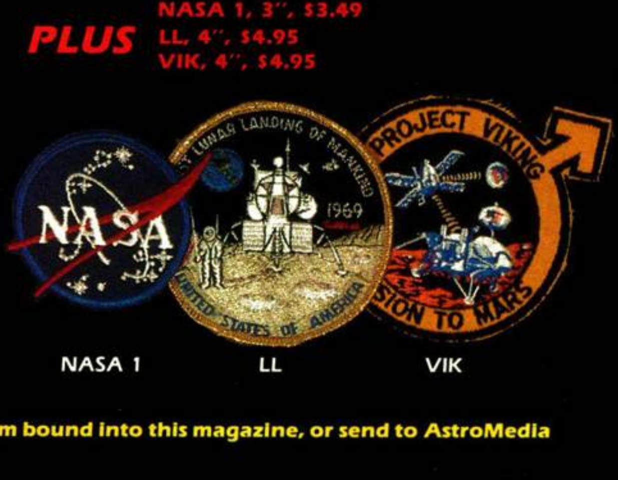
NASA 1
LL
VIK

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